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ORIGINAL ARTICLES.

Odontocaulis Lapworth, a synonym of *Callograptus* Hall.

By O. M. B. Bulman, Ph.D., D.I.C., A.R.C.S.

1881. *Odontocaulis* Lapworth, *Q.J.G.S.*, vol. xxxvii, pp. 175, 176.
1897. ,, Pocta, *Syst. Sil. Centre Bohême*, vol. viii, p. 171.
1908. ,, Ruedemann, *N.Y. State Mus.*, *Mem.* 11, pp. 172–4.
1909. ,, Bassler, *U.S. Nat. Mus.*, *Bull.* 65, p. 42.

Genotype : O. keepingi Lapworth, 1881, loc. cit. The species was founded on a single specimen from the Llandovery of Devil's Bridge, near Aberystwyth ; all efforts to trace this specimen have failed.

I. Generic Diagnosis.

The original generic diagnosis is as follows :—

" Polypary cyathiform, composed of numerous independent and frequently bifurcating polypiferous branches, originating from the distal extremity of a short stem, which is likewise polypiferous and is terminated proximally in an irregular corneous expansion. Hydrothecae of the type of those of *Dictyonema*, biserial, subalternate.

" The chief peculiarity of this genus is afforded by the character of the stem, which is identical in every respect with the main branches, and, like them, is denticulate or polypiferous throughout the whole of its extent. It commences proximally in a flattened expansion, with irregular or frayed-out edges, possibly the remains of a disk or bulb of attachment.

" The mode of branching is rigidly dichotomous, the first two branches being formed by the sub-division of the main stem itself. Each arm branches and rebranches again and again in the same manner, at frequent and close intervals, composing an elegant cyathiform or fan-like polypary, very symmetrical in form. The branches retain their original width to their final division, which gives rise to two minute branches less than one-tenth of an inch in length.

"The hydrothecae are more prominent than those upon *Dictyonema.* The distal extremity of each appears to have been free and slightly introverted, as in the majority of the bilateral family of the Dicranograptidae.

"*Odontocaulis* is separated from *Dictyonema* by the absence of the transverse dissepiments, and by the polypiferous character of the stem. From *Callograptus,* which it much resembles, the same features effectually distinguish it. In *Dendrograptus* the stem is stout and devoid of polypes, while the branches are irregularly disposed; in the present genus the stem is no thicker than the branches, is polypiferous, and the branches are regularly and symmetrically subdivided. It has probably its nearest ally in *Rhizograptus* (Spencer, *Canadian Naturalist,* 1879, p. 460); but in that genus the stem appears to be barren, and the branches are possibly united at intervals."

In his diagnosis of the genotype, *O. keepingi,* Lapworth emphasized that "the branches . . . are quite free and independent, neither inosculating, as in some forms of *Dictyonema,* nor being connected by transverse dissepiments, as in that genus and its ally *Callograptus*".

The genus was thus founded to include forms with the following characters:—

(1) A stem bearing hydrothecae—the feature of prime importance, recognized in the selection of the name.
(2) Independent and frequently bifurcating stipes, and
(3) Prominent hydrothecae.

These features, combined with the relative slenderness of the stem, the symmetrical branching, and the absence of dissepiments, served to distinguish it from its allies *Dictyonema, Callograptus, Dendrograptus* and *Rhizograptus.*

II. GURLEY'S EMENDED DIAGNOSIS.

In their discussion of *Odontocaulis,* Ruedemann (1908, loc. cit.) and Bassler (1909, loc. cit.) both quote freely from a manuscript description prepared by Gurley. The latter accepted as referable to the genus the species *O. occidentalis* Gurley MS., Bassler, which possesses dissepiments and a thecate stem. It would appear, from the published figures, that the dissepiments occur sporadically as in some species of *Callograptus,* but do not produce the regular meshwork characteristic of *Dictyonema.* The same combination of features is present in *O. obpyriformis* Gurley MS., Bassler, although the dissepiments seem here to be more abundantly developed, as

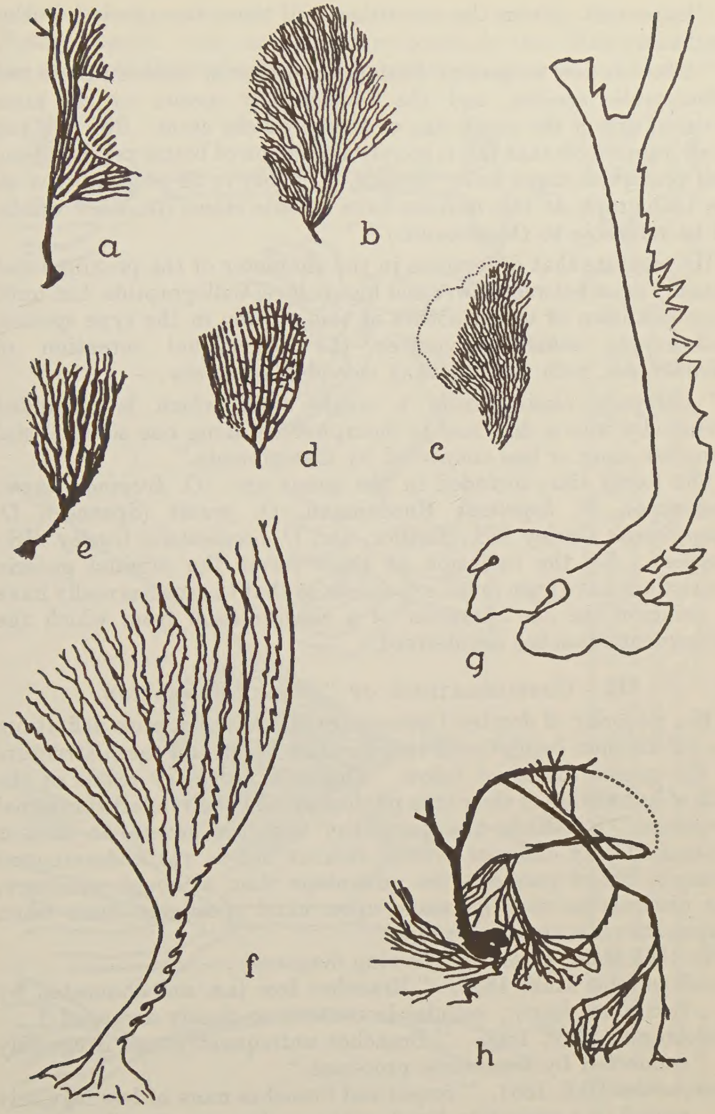

FIG. 1.—*a, Odontocaulis occidentalis* Gurley MS., Bassler, 1909, op. cit., p. 44, fig. 56; *b, O. granti* (Spencer), Bassler, op. cit., p. 42, fig. 53; *c, O. granti* (Spencer), Bassler, op. cit., fig. 54; *d, O. obpyriformis* Gurley MS., Bassler, op. cit., p. 43, fig. 55; *e* and *f, O. keepingi* Lapworth, 1881, op. cit., p. 176, pl. vii, figs. 7*a, b* (*e*, ×1, *f*, ×5); *g, O. hepaticus* Ruedemann, 1908, op. cit., p. 174, fig. 79 (×6); *h, O. hepaticus* Ruedemann, op. cit., pl. i, fig. 6 (×1).

in *Dictyonema.* From the constitution of these two species, Gurley concludes :—

"There is now no generic distinction whatever between these two *Odontocaulis* species, and the *Callograptus* species at the same horizon, except the single one of thecae on the stem. But it is not at all improbable that this is merely a question of better preservation, well-preserved stems being thecate. . . . May it be possible that *all* the Callograpti at this horizon have thecate stems (in other words, all be referable to *Odontocaulis*) ? "

He suggests that differences in the character of the proximal end possibly exist between lower and higher level Callograptids, but until more is known of the structure of this portion in the type species, *Callograptus salteri,* advocates the provisional retention of *Odontocaulis,* with the following emended diagnosis :—

"Polypary arising from a single stem which is expanded proximally into a disk and is thecaphorous along one side ; distal branches more or less connected by dissepiments."

The forms thus included in the genus are : *O. keepingi* Lapw. (genotype), *O. hepaticus* Ruedemann, *O. granti* (Spencer), *O. obpyriformis* Gurley MS., Bassler, and *O. occidentalis* Gurley MS., Bassler. By the inclusion of these forms the original generic restrictions have been much expanded, so that the species really have in common the one character of a thecate stem from which the subsequent branches are derived.

III. CONSIDERATIONS OF "STEM"-FORMATION.

The majority of dendroid genera are difficult of precise definition, the subdivision being based largely upon habit and mesh-structure in the genera discussed below. This is a necessary result of the lack of knowledge of their true phylogeny and their detailed internal structure. It admits the possibility that the genera at present recognized may embrace several distinct but as yet undetermined lineages, but it possesses the advantage that, although arbitrary, the distinctions may be made upon hand specimens even when fragments only are preserved.

In 1865 Hall[1] gave the following diagnoses :—

Dendrograptus Hall, 1858. "Branches free (i.e. not connected by transverse bars) ; cellules in contact or closely arranged."

Callograptus Hall, 1865. "Branches unfrequently and irregularly connected by transverse processes."

Dictyonema Hall, 1851. "Stipes and branches more or less regularly united in a reticulate frond, without elongate stem."

Elsewhere he remarks (op. cit., p. 133) of *Callograptus* :—

"Flabellate fronds, with numerous slender bifurcating branches proceeding from a strong stem or axis," and refers (op. cit., p. 126) also to a "strong footstalk" in *Dendrograptus*. One may therefore conclude that Hall considered the genera *Callograptus* and *Dendrograptus* to have been attached by a definite stem, but that *Dictyonema* was not so organized. More recent work[1] has shown that certain species, which seem truly

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[1] Hall, *Geol. Surv. Canada, Canadian Organic Remains,* 1865, dec. 2 ; *Graptolites of the Quebec Group,* p. 51.

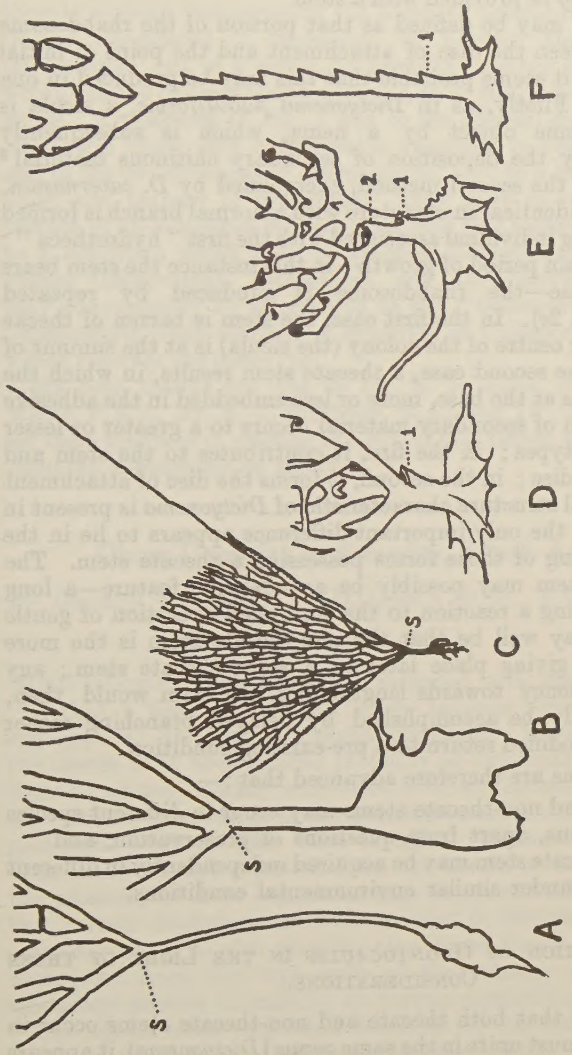

Fig. 2.—A, secondarily strengthened nema attachment (*Dictyonema flabelliforme*, ×5, after Hahn, op. cit., pl. xxi, fig. 4*b*); B, non-thecate stem (*D. flabelliforme*, ×5, after Hahn, op. cit., pl. xxi, fig. 3*b*); C, non-thecate stem (*D. flabelliforme*, ×1, after Matthew, *Trans. N.Y. Acad. Sci.*, 1895, vol. xiv, pl. xlix, fig. 1); D, diagrammatic representation of rooted, stemless *Dictyonema*; E, short thecate stem (*D. cavernosum*, ×10, after Wiman, 1896, op. cit., pl. i, fig. 1); F, long thecate stem, "*Odontocaulis* condition" (based on an undescribed *Dictyonema* from Girvan, B.M. (N.H.), H 1726). *s*, sicula; 1, initial "hydrotheca"; 2, second hydrotheca. (These forms are figured erect, but there is no positive evidence of their direction of growth.)

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[1] C. Wiman, *Bull. Geol. Inst. Upsala*, 1896, vol. iii, no. 5, pp. 1–13; 1897, vol. iii, no. 6, pp. 352–5.

referable to *Dictyonema*, may be provided with a stem and root-like disc or fibres, and also [1] that these forms have essentially the same structure as the siculate forms. We must therefore allow that all three genera *may* be provided with a stem.

The "stem" may be defined as that portion of the rhabdosome which lies between the disc of attachment and the point of initial branching, and it seems probable that this may be produced in one of two ways. Firstly, as in *Dictyonema flabelliforme*, a sicula is attached to some object by a nema, which is subsequently strengthened by the deposition of secondary chitinous material [2] (Fig. 2*a–c*). In the second method, exemplified by *D. cavernosum*, a stem which is identical in structure with a normal branch is formed from the budding individual associated with the first "hydrotheca"; following a certain period of growth—in this instance the stem bears two hydrothecae—the rhabdosome is produced by repeated dichotomy (Fig. 2*e*). In the first case, the stem is barren of thecae and the growing centre of the colony (the sicula) is at the summit of the stem; in the second case, a thecate stem results, in which the growing centre is at the base, more or less embedded in the adhesive disc. Deposition of secondary material occurs to a greater or lesser extent in both types; in the first it contributes to the stem and forms the basal disc; in the second, it forms the disc of attachment only. The thecal structure characteristic of *Dictyonema* is present in both types, and the only important difference appears to lie in the delayed branching of those forms possessing a thecate stem. The length of the stem may possibly be an adaptive feature—a long flexible stem being a reaction to the continued operation of gentle currents. It may well be that the non-thecate stem is the more primitive type, giving place later to a short thecate stem; any subsequent tendency towards lengthening the stem would then, perhaps naturally, be accomplished by delayed branching rather than by an unmodified return to a pre-existing condition.

The suggestions are therefore advanced that:—

(*a*) Thecate and non-thecate stems may occur in different species of the same genus, apart from questions of preservation, and

(*b*) A long thecate stem may be acquired independently in different genera existing under similar environmental conditions.

IV. THE POSITION OF *ODONTOCAULIS* IN THE LIGHT OF THESE CONSIDERATIONS.

From the fact that both thecate and non-thecate stems occur in forms which we must unite in the same genus (*Dictyonema*), it appears that there is now no valid distinction between *Odontocaulis* and *Callograptus*—the genus which would naturally accommodate the genotype, *O. keepingi.* It remains true that, as remarked by Gurley, we do not yet know the structure of the stem in the genotype of *Callograptus*, but by analogy this could either be thecate or non-thecate without transgressing the accepted limitations of the genus. Gurley considered it necessary to expand the definition of *Odontocaulis*, but as a result, he brought together a group of forms which cannot be transferred *en masse*, as he suggested, to some other genus. A reference to Fig. 1 and to the original descriptions there cited, will show very considerable variation in rhabdosome shape and in the development of dissepiments, and, to a less extent, in the habit and manner of branching. They have in common the one feature of an elongated thecate stem, and this seems better regarded as a condition which may be reached independently in the three genera *Callograptus*, *Dictyonema*, and *Dendrograptus*, and which may conveniently be referred to as the "*Odontocaulis* condition". *Odontocaulis* itself becomes a synonym of *Callograptus* Hall, 1865, which receives the genotype.

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[1] *Palaeont. Soc., Mon. Brit. Dendr. Grapt.*, pt. i, pp. 11, 17–21.

[2] F. F. Hahn, *Ann. N.Y. Acad. Sci.*, 1912, vol. 22, pl. 21.

My best thanks are due to Dr. G. L. Elles, Professor W. W. Watts, F.R.S., Mr. A. G. Brighton, M.A., and Dr. C. J. Stubblefield for their kindness in reading the MS. of this paper, and for the many valuable suggestions so received.

Chert Deposits in Ecuador, South America.

By George Sheppard, Ph.D.(Lond.), B.Sc., F.G.S., M.I.Min.E.

(PLATE XIII.)

THE following notes have been recorded with the idea of showing that a field relationship exists between true chert veins or aggregations, and certain igneous intrusions. Beyond the fact that the cherts have been formed probably as the result of some hydrothermal agency, usually associated with, and occasionally the result of, volcanic episodes, it is not possible to enter more fully into the geological origin of this form of silica. Microscopic fossils have been observed and recorded from the cherts of Santa Elena,[1] but the presence of these organisms may be accounted for by the fact that certain Radiolaria are able to exist in waters of a fairly high temperature, it is also possible that these fossils may have been abstracted from the vein walls of the country rock during the secondary process of infilling by crypto-crystalline silica.

The sketch-maps appended herewith by no means indicate the whole of the dyke and chert occurrences which are found in this part of the country ; many more undoubtedly exist, but only those which have actually been mapped by the writer are shown.

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[1] Joseph Sinclair and Charles P. Berkey, *Cherts and Igneous Rocks of the Santa Elena Oilfield, Ecuador*, New York.

GEOGRAPHICAL DISTRIBUTION.

As referred to above, the respective outcrops of chert and igneous rock indicated in Figs. 1 and 2 do not limit the entire distribution of these phenomena in southern Ecuador. Other occurrences of a similar nature are found, especially in the province of Manabi to the north, and it is known that an easterly extension of the map (Fig. 2) would reveal further outcrops of these rock types. The

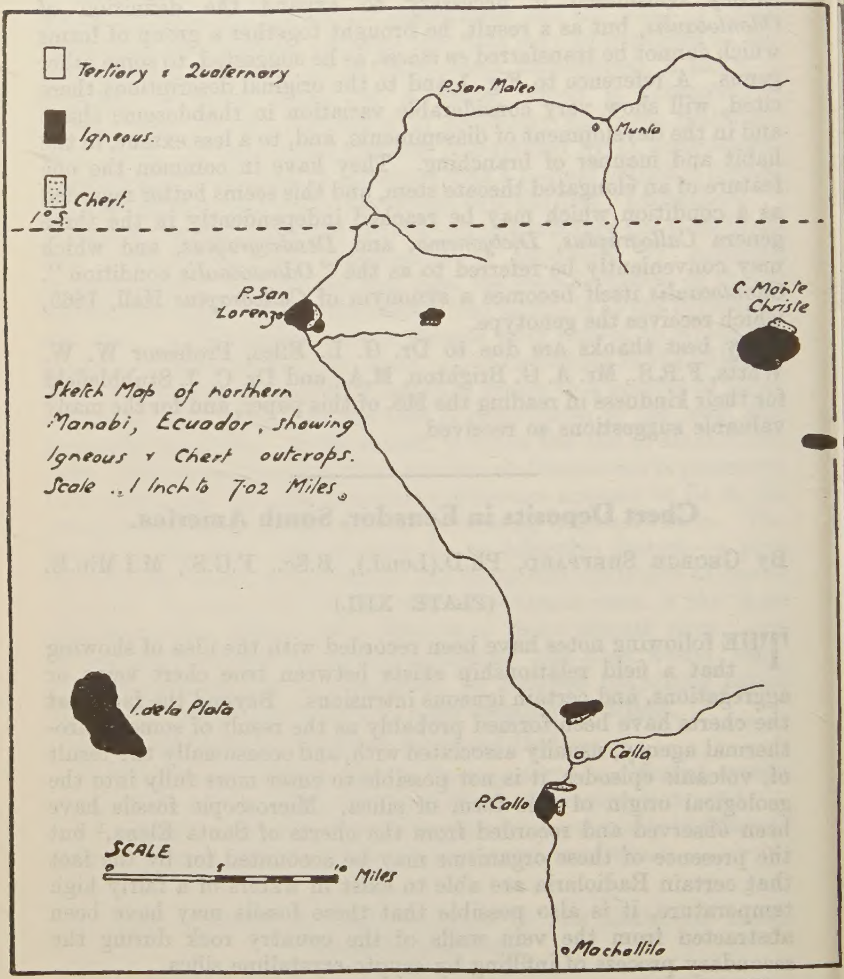

FIG. 1.—Sketch-map of the northern part of the province of Manabi, showing principal intrusions and chert outcrops. Scale : 1 inch to 7·02 miles.

areal geology of this district includes Recent, Quaternary, and Tertiary deposits, whilst post-Tertiary intrusions are very common, the most important being known as the Cerro de Monte Cristo. The latter conspicuous hill forms but one of a series of similar intrusions, the most westerly on the mainland occurring at Punta San Lorenzo. Masses of chert are invariably found in close association with this series of dyke rocks.

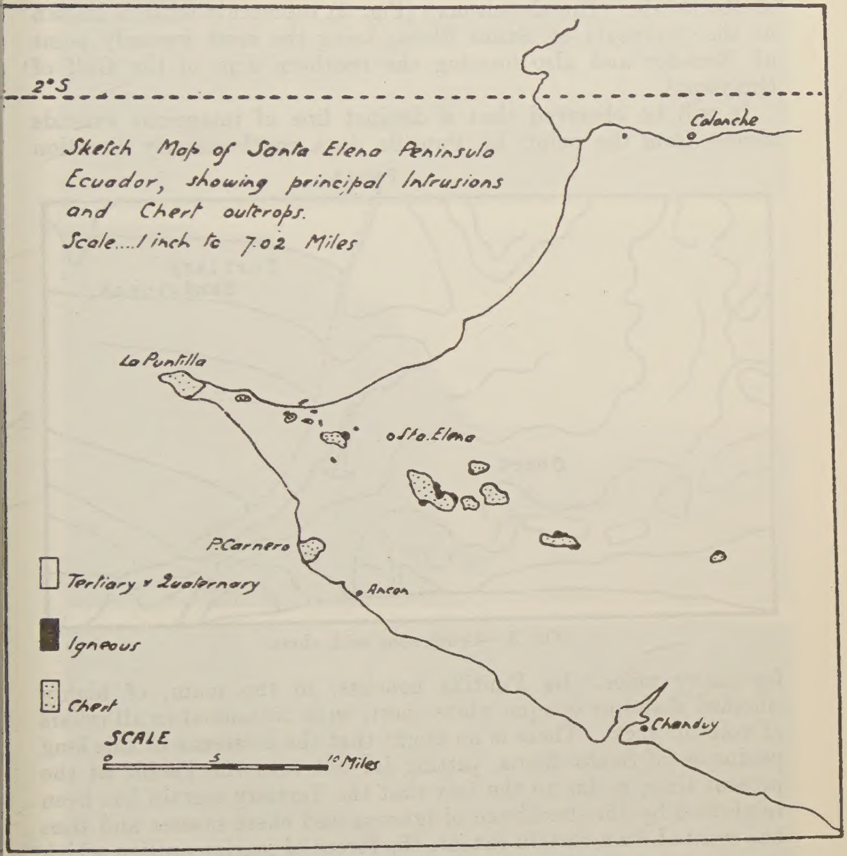

Fig. 2.—Sketch-map of Santa Elena peninsula, Ecuador, showing principal intrusions and chert outcrops. Scale: 1 inch to 7·02 miles.

Further to the south also a group of intrusions can be examined in the neighbourhood of Callo and inland for about ten miles. The most westerly outcrop of the latter is known as Isla de la Plata, an island consisting entirely of a basaltic type of volcanic rock, superimposed by thin tablazo deposits of Quaternary age.[1]

The headland known as Punta Callo is actually a dyke formation which has intruded the Tertiary shales and sandstones (Pl. XIII). A striking series of metamorphosed shales with attendant cherts can be observed also from this point southwards in the direction of Machallila. The sketch-map (Fig. 2) represents what is known as the peninsula of Santa Elena, being the most westerly point of Ecuador and also forming the northern arm of the Gulf of Guayaquil.

It will be observed that a distinct line of intrusions extends almost from the point, La Puntilla, in a south-easterly direction for many miles. La Puntilla consists, in the main, of highly silicified shales or opaque white chert, with occasional small inliers of volcanic rock. There is no doubt that the existence of this long peninsula of Santa Elena, jutting far out into the Pacific at the present time, is due to the fact that the Tertiary terrain has been reinforced by this backbone of igneous and chert masses and thus has resisted, to a certain extent, the forces of marine erosion which are very intensive along this section of the coast.

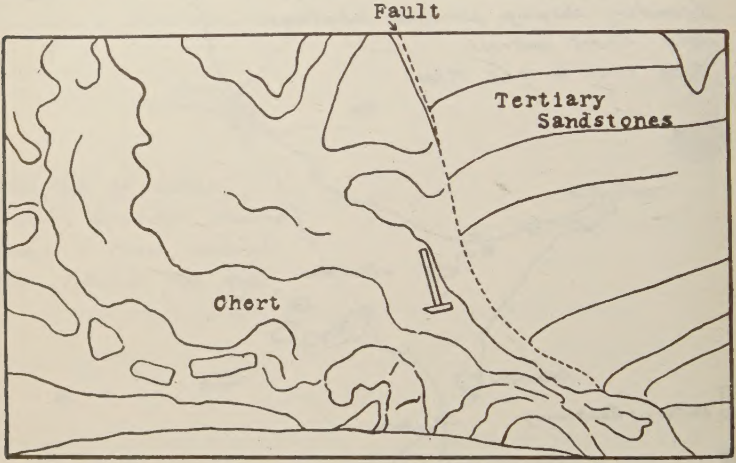

FIG. 3.—Crush zone with chert.

Fig. 4 represents a map of a portion of the principal chert-igneous complexes on a larger scale, this occurring to the south-east of the town of Santa Elena. Although this area is disturbed considerably, it will be noticed that the cherts and dykes are intimately associated in the field, and undoubtedly have some connection the one with the other.

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[1] G. Sheppard, "Geological Observations on Isla de la Plata, Ecuador, South America": *Amer. Journ. Sci.*, 5th ser., vol. xiii, 1927.

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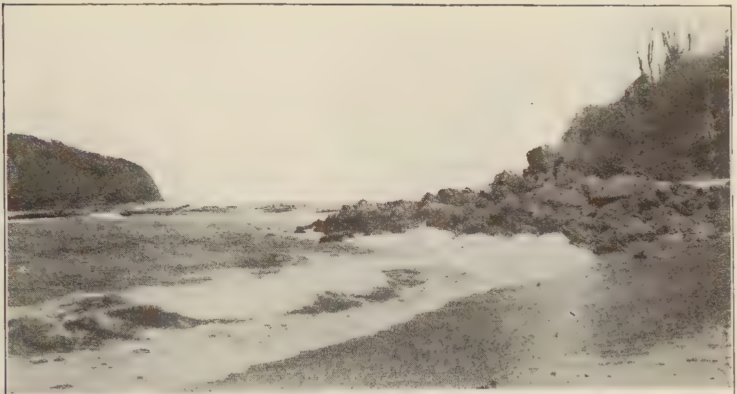

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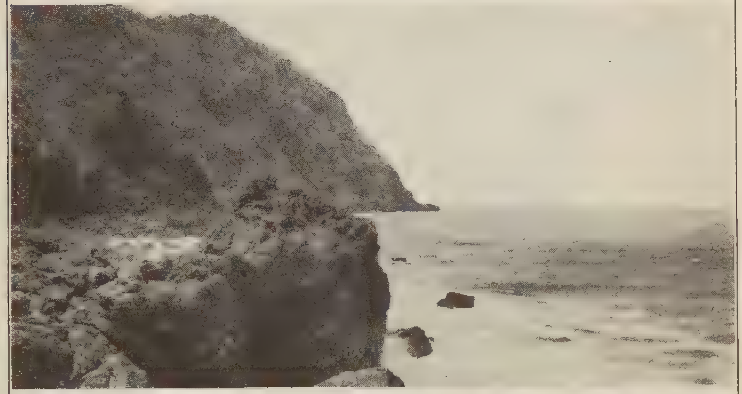

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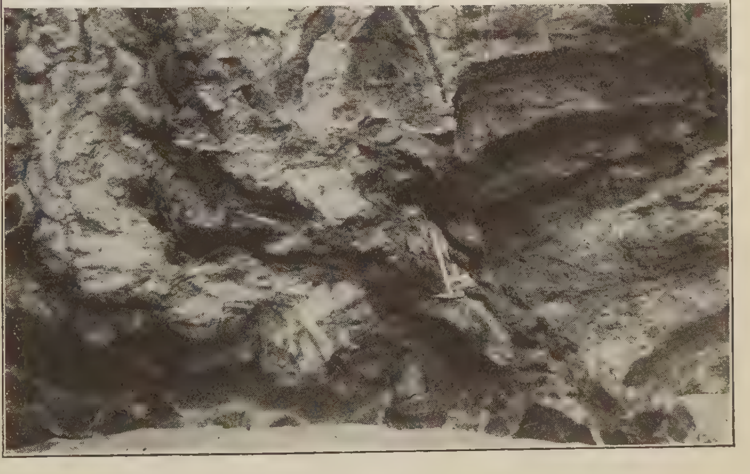

FIG. 1.—Punta Callo, Ecuador.

FIG. 2.—Punta Callo, Ecuador, showing nature of dyke. Masses of chert are found in close proximity.

FIG. 3.—Crushed and faulted zone in Tertiary formations near a volcanic intrusion. (Punta Callo, Ecuador.)

[*To face p. 346.*

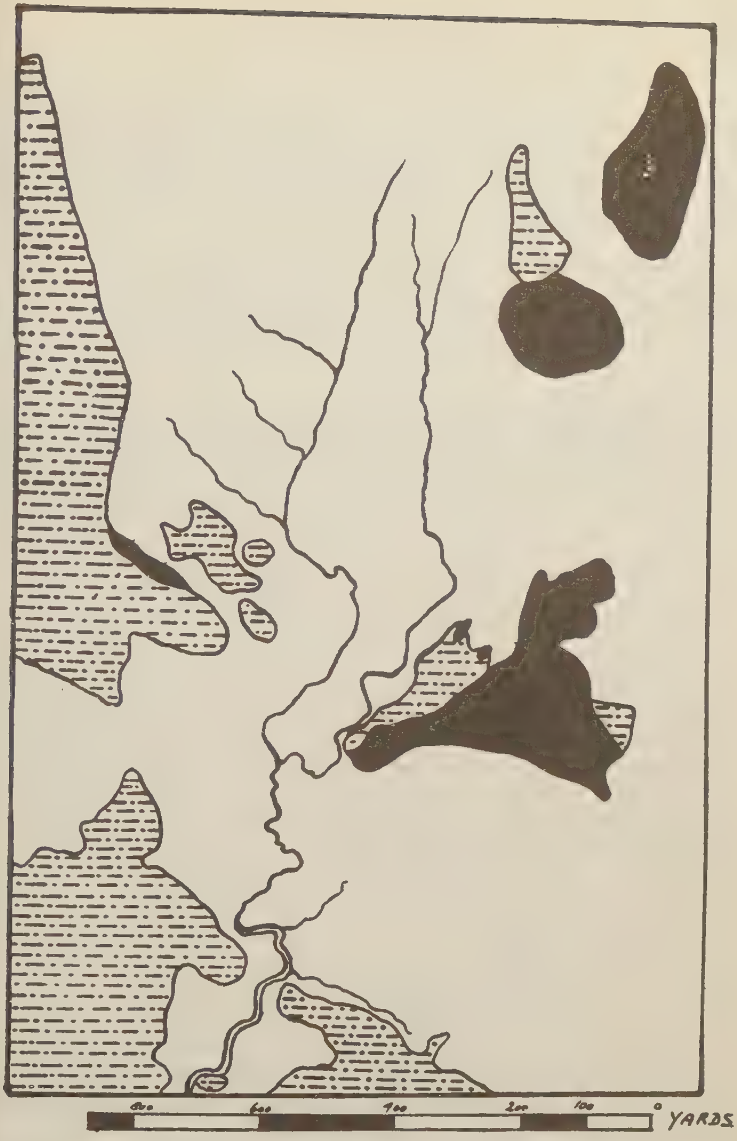

FIG. 4.—Sketch-map of chert-igneous complex to the south-east of Santa Elena, Ecuador. (After Murray.) Scale: 6·3 inches to 1 mile.

☐ Recent, Tertiary and Quaternary.

▤ Chert.

■ Igneous.

MODE OF OCCURRENCE.

The greater part of the coast-belt or littoral of southern Ecuador consists principally of Quaternary and Tertiary deposits, the latter, for the most part, being made up entirely of sandstones, shales, and occasional conglomerates. These formations, however, have been altered locally near the presence of volcanic dykes. The Quaternary deposits are known as tablazos and these consist, in effect, of raised beaches, or sea-floors, which extend over a large area. The tablazos always cover the Tertiary formations unconformably and in no case has a dyke been observed to penetrate the tablazo. The dykes, therefore, are of post-Tertiary and pre-Quaternary age.

In the region under consideration the cherts are found in irregularly disposed masses among the shales and sandstones wherever the latter deposits have been changed, in a lithological sense, by the metamorphism induced by the post-Tertiary intrusions. The cherts are apparently true vein-deposits of secondary origin and vary in size from microscopic "stringers" to enormous masses measuring several feet across.

Observations in the field have established the corollary that wherever cherts are found in association with the Tertiary formations of this region, volcanic dykes and zones of metamorphism can be expected. In many cases the cherts seem to consist entirely of translucent, colourless silica, but other occurrences present a variety of types, each of which has been determined by the local conditions under which the segregation of silica took place, and by the chemical nature of the country rock. In this latter respect it is of interest to note the composition of the typical shales of this region and to cite the following analysis:—[1]

UPPER EOCENE SHALE, QUEBRADA ENGABAO.

	%
Moisture	9·24
Silica	78·19
Iron oxide and aluminium oxide	10·74
Calcium carbonate	1·59
Magnesium carbonate	·24

From the above it will be seen that these shales have a high silica content, it being probable that, in the first instance, they originated from the denudation of an extensive Cretaceous land-mass to the north and east of the present coast.

A series of indurated sediments, therefore, consisting of argillites and porcellanites, has resulted near an igneous dyke where the latter has intruded the Tertiary formations. These altered types are invariably characterized by the presence of innumerable shrinkage cracks which have been caused apparently by the rapid cooling of the contact zone shortly after the initial intrusion. As will be referred to below, these minute planes or joints were later infiltrated by secondary silica, this being due, in all probability, to the influences of hydrothermal action.

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[1] Analysis by L. F. Whitfield.

An opaque white chert collected from a dyke-contact near San Vicente yielded the following analysis:—

	%
Moisture	1·27
Silica	80·07
Iron oxide and aluminium oxide	1·59
Calcium carbonate . . .	16·81
Calcium sulphate . . .	·26

(Cf. analysis, above.)

The massive forms of amorphous chert have a more complicated history, and from the field evidence it can be suggested only that they have been aggregated under one or more of the following conditions:—

1. In a crush-belt or shatter-zone in the vicinity of an intrusion. (Fig. 3.)
2. Along a slickensided joint, and in the bedding planes contiguous to the displacement.
3. In a solution cavity formed in the metamorphosed sediments.

In the first case the chert has usually a brecciated appearance, the angular fragments of opaque silica having been enclosed more or less ophitically in a translucent matrix of the same material. In this type the chert is vari-coloured from brown to yellow, and the matrix itself has been permeated by small veins or inflorescences of coloured silica.

In almost every example the dominant colour has been determined primarily by the alteration of a natural iron compound indigenous to the country rock. In connection with this type of siliceous aggregation the genetic history can be traced in at least three stages. Owing to the initial nature of the crush belt in which the chert occurs it is obvious that the joint, or plane of dislocation will contain angular fragments of either indurated shale or the altered sandstone elements which are found occasionally intercalating the shale deposits. The latter always possess a fairly high iron content, either in the form of an oxide or a carbonate.

The three principal stages, therefore, can be outlined briefly as follows:—

(*a*) A crush-belt of angular shale or sandstone in the dislocated zone near the intrusion. This breccia would no doubt be in a state of compression owing to the rock pressure, but no infiltration or hydrothermal silicification would take place until after a considerable interval of time.

(*b*) A gradual deposition of silica formed around the constituent fragments of the above breccia would then follow, with a separation of the ferrous compounds. At the same time a partial replacement of the breccia by amorphous silica would be initiated, the various colours resulting from the degradation of the iron compounds present in the brecciated material.

(*c*) The final and complete replacement by silica then follows, which would result in a homogeneous aggregation of chert enclosing the angular fragments of the primary crush-breccia.

In example 2 the chert has a slightly banded aspect and also appears to be traversed by a series of shrinkage planes or minute faults. In this case it is possible that the whole siliceous mass has been fractured subsequent to consolidation by the action of a later rock movement which operated along the original slickensided zone. Normally, this type of chert is fairly homogeneous and has been formed probably as a true example of siliceous infiltration with little admixture of coloration such as has been described under 1.

Finally, in 3, the chert has been formed in a rock cavity occurring in the indurated formations, and has been aggregated through a process of leaching comparable to the growth of an agate in the vesicle of a decomposed volcanic lava. The massive forms of chert can be assigned probably to the above class, their irregular and fantastic shapes having been governed by the contour of the cavity itself.

It is of interest to note that the massive cherts present the greatest variation in colour, and although the range is fairly extensive, from white, reds and browns, to black it has been observed that the red varieties are usually associated with altered sandstones, or shales containing an appreciable sandstone element, whilst the greyish-white forms are found only in the shales. Summarizing, therefore, the varieties of chert found in this region include the following :—

(1) *Black Vitreous Chert.*—This is a compact, jet-black semi-translucent type which has the general appearance of an obsidian. It rarely occurs massive but is characterized by an in-veining habit, being intercalated amongst other grey or white chert aggregations. Not infrequently the white cherts, probably derived from the silicified shales, are minutely veined with the black variety, and the latter thus forms a striking contrast to the matrix.

The black chert is also found in irregular groupings which are more or less lenticular in habit, and these appear to indicate a certain parallelism in the country rock. It is possible that the strain cavities in the parent rock, due to subsequent differential movement, have been filled in secondarily by the translucent variety of silica. The latter, however, is peculiarly hard and hence weathers out conspicuously from the surface of the lighter-coloured cherts. The dark colour of the rock is due probably to included carbonaceous material after the manner of true black flint, and it may also contain magnetite in a comminuted or ultra-microscopic form. The exposed surfaces of the black chert weather to white or grey as in normal flint, and it is possible that this phenomenon is due to its porosity and to the partial solution induced by the action of capillary water.

(2) *White Opaque Chert.*—The white cherts are probably the most widely distributed forms in the whole area under consideration. The field evidence appears to confirm the view that the white cherts represent an advanced stage of a silicified shale: they are also found commonly in association with igneous outcrops. The fact that certain microscopic organisms in a fossil state have been recognized in this and allied forms of chert is not surprising, as the unaltered Tertiary formations contain Radiolaria and Foraminifera in considerable profusion. The chert has the normal hardness of ordinary silica, and breaks with a conchoidal fracture. It is fairly brittle, however, this phenomenon being probably explained by the fact that the matrix is usually intersected by minute cracks or joints.

This variety of chert is found in large masses which weather out as hills or conspicuous outcrops in the general topography of the country. Whilst signs of stratification can be detected usually in connection with this type of formation, the individual beds are disturbed and shattered, a condition which has no doubt been occasioned by the proximity of volcanic dykes. In the San Vicente region, to the east of Santa Elena, dykes can be seen in actual contact with the cherts, whilst at La Puntilla where large outcrops of this variety are found, small dykes or isolated inliers of igneous rock can be seen involved in the siliceous groundmass itself. These latter occurrences are peculiar, and it is difficult to explain why these blocks of igneous material should be so enclosed in the irregularly disposed masses of white chert. It is obvious, however, that they follow certain trends or planes in the chert and it is possible that they represent a selvedge or fringe of a more deep-seated dyke which has been forced upwards along a fracture plane during the final consolidation of the intrusion.

As referred to above (1), this variety of chert is frequently veined by black, flinty silica, and the latter also appears to occupy the strain-cavities which are found in the parent white chert.

Large spheroidal masses of banded chert occur commonly in association with the white and grey varieties. These can be designated " Augen Cherts ", and will be described below.

(3) *Augen Chert.*—In many localities the Augen Cherts are found in association with the white variety. In rare cases they are slightly coloured, but they are distributed more commonly amongst the grey or white types. The " augen " vary in size from a few inches to two or three feet in diameter and they are generally ellipsoidal or egg-shaped. Apparently they are non-nuclear but present concentric bands of silica (black or translucent) alternating with the white chert. In this respect they are very similar to the banded flint which is found in the Cretaceous formations of England and other countries.

From the hand specimen it seems possible that the banded varieties of chert had an origin in the white opaque type, and appear to be a secondary form resulting from a separation of the clear silica in defined bands. On the other hand, the augen are invariably traversed by cracks or veins in an irregular manner, and these are always filled with translucent or clear silica.

In certain specimens collected from the opaque chert incipient banding can also be observed. This always appears in the matrix as originating from a transverse vein. It is possible, however, that the latter has been derived in a secondary manner from the siliceous material constituting the concentric banding in the groundmass of the rock.

The respective laminae of the augen flake off separately upon exposure to the atmosphere, this being due possibly to the relative hardnesses of the two forms of silica. It has been observed also that the white opaque chert is distinctly porous when compared with the translucent variety. No explanation can be offered to account satisfactorily for the banded habit of these cherts. It can be suggested tentatively, however, that as the clear silica forms the concentric bands in the augen, apparently ramifying from the transverse veining, there is probably some connection between the two siliceous forms (Fig. 5). It seems improbable that the augen cherts have been formed after the manner of an agate. The respective bands do not suggest phases of siliceous deposition, but rather they represent successive infiltrations probably associated with internal leaching within the chert mass itself.

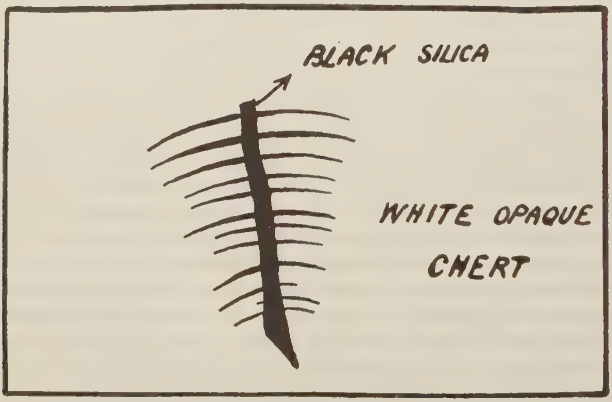

Fig. 5.

(4) *Brecciated Cherts.*—As referred to previously, the brecciated cherts are usually found in association with altered sedimentaries which have been deformed along a fault plane, or the plane of an overthrust. Wherever intense tectonic movement has affected the original disposition of the Tertiary beds, local crush zones have been formed, and very often these have been filled with typical crush-breccias derived from the country rock. In addition to this

type a further example can be quoted where an open joint in the stratified rocks has been filled in by weathered angular fragments fallen from the rock walls of the cavity. With the exception that the latter material is more loosely consolidated, the two types of breccia are difficult to differentiate, without reference to the disposition of the contiguous strata. As a rule, the brecciated cherts are vari-coloured and it has been observed that the highly coloured forms, namely, the reddish varieties, are nearly always present where a dyke has invaded an arenaceous formation, whilst the grey, black and light-coloured varieties indicate the alteration of shales or similar strata of argillaceous derivation.

The precise mineralogical and chemical changes which have taken place in producing the phenomena displayed by these cherts and silicified shales have not yet been worked out for this area, but as these types of rock are often found as dyke-contacts they must represent a series of secondary formations induced possibly by the addition of the silica element from the dyke (though the dykes are basic in composition) or by the degradation of the original shales and sandstones as a consequence of thermal metamorphism. Several low hills consisting of whitish chert are found in the San Vicente region and in two instances, at least, a coarse andesitic type of igneous rock can be seen in contact with the altered sedimentaries. In every case, also, where the indurated shales and cherts occur, the strata are shattered and distorted very considerably, and it is possible that the minor structural features of the geology of this region are primarily due to the presence of this series of intrusions. It is assumed, therefore, that the opaque white cherts are silicified shales caused by the alteration of the original Tertiary formations.

The true sandstones, however, when metamorphosed, present equally striking features. They are usually characterized by a distinctive reddish colour, and they are also indurated and silicified to such an extent that they approach a true quartzite in appearance and constitution. In the majority of cases the bedding planes of the sandstone are still preserved, but the whole body of the rock has been changed into a hard, siliceous material, which is very flinty and tenacious in texture.

CONCLUSIONS.

(1) The cherts occurring in the region under consideration have a distinct connection with the presence of igneous intrusions.

(2) Two major classes of chert can be recognized :—

(*a*) *Primary.* Vein material infilling natural cavities and planes of structural displacement. This class of chert has been deposited from solution as a direct result of proximity to igneous intrusions.

(*b*) *Secondary.* Tertiary shales which have become completely silicified—a probable result of contact metamorphism and injection.

A System of Joints on the Surface of Basalt Columns at the Giants Causeway.

By Herbert P. T. Rohleder, Ph.D., Royal College of Science, London.

(PLATES XIV AND XV.)

WHEN studying the geology of the Giants Causeway district in 1924 I noticed a strange system of well-developed joints on the surface of some basalt columns. As these only appeared on the planes of a few columns in this district, where several hundred thousand basalt columns are exposed, and as these joints were only to be found on and quite close to the surface, I firstly regarded them as a mere feature of weathering.[1] It was only after Professor Dr. Maximilian Weber in Munich pointed out to me the striking resemblance of these joints to the photos published in Daubrée's *Études synthétiques de Géologie Experimentale*, and I decided to investigate this problem closer, the results of which are given as follows :—

This system of joints is only to be found at one locality in the Giants Causeway district, i.e. the lower parts (sea level) of the " Grand Causeway " (west side) opposite the " wishing chair " (the spot is marked with a white X on Fig. 1, Pl. XIV).

The columns show a diameter of approximately 1 to 2½ feet. The joints usually only occur on the top of the column, and then even a few inches under the surface the basalt shows the ordinary structure, but in several cases the continuation of these joints, parallel to the longitudinal axis of the column, is to be found even up to 16 inches, where a neighbouring column hides the latter (*vide* Fig. 2). The joints run from one side of the column to the other (*vide* Figs. 3 and 4), and frequently show continuation on one or even several of the neighbouring columns. Occasionally the direction of one or several of the joints coincides with the direction of the edges of the column, as naturally would be the case considering the hexagonal form of the surface of the columns, but this does not seem to follow any law.

Four directions of the joints are generally to be found, the most distinctive one striking 145 degrees (35 degrees east of south and west of north) proved to be open. Perpendicular to this direction (strike 53 degrees) indistinct joints occur, which are only to be traced occasionally as they do not show the open character of the former. Intermediate between these two joints regarding distinctness there is a pair of diagonal joints (strikes 25 and 90 degrees), and lastly a sort of horizontal jointing parallel to the surface and coinciding with the planes of cooling of the basalt columns (*vide* Pl. XIV, Fig. 2, and Pl. XV, Figs. 3 and 4).

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[1] H. P. T. Rohleder, "Das Giants Causeway Gebiet": *Zeitschrift für Vulkanologie,* 1927, Berlin.

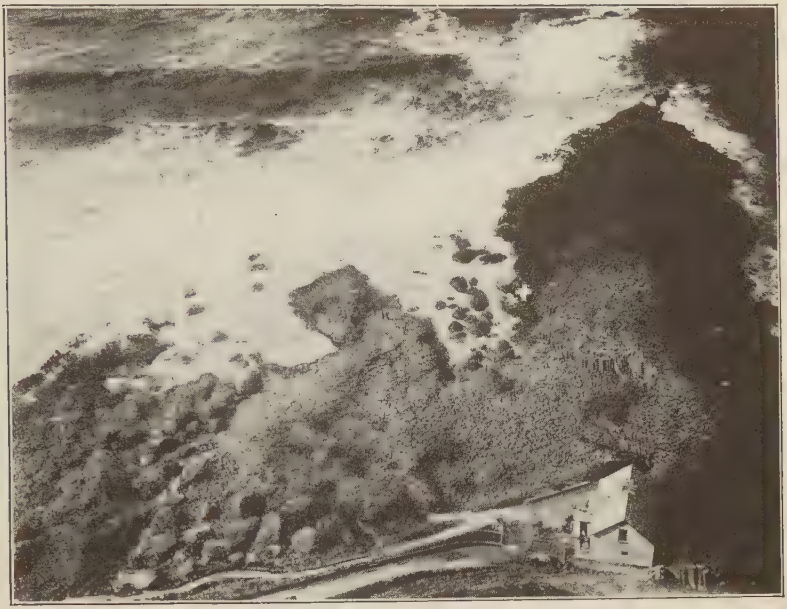

FIG. 1.—"THE GRAND CAUSEWAY," GIANTS CAUSEWAY.

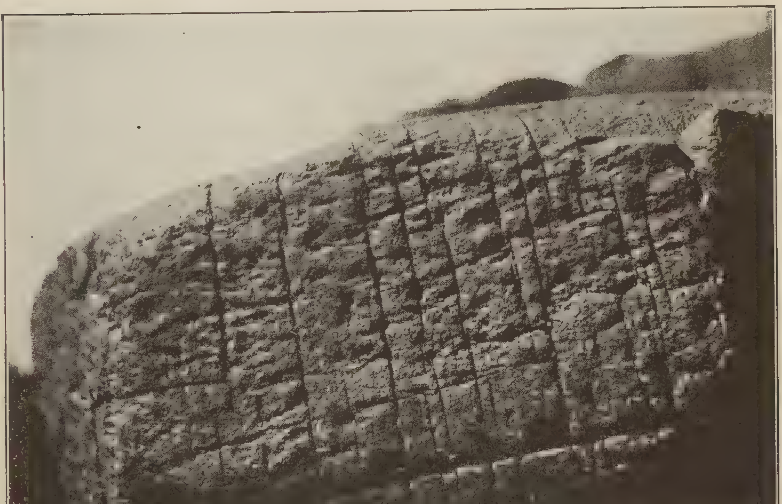

FIG. 2.—JOINTS IN BASALT, GIANTS' CAUSEWAY.

[*To face p. 354.*

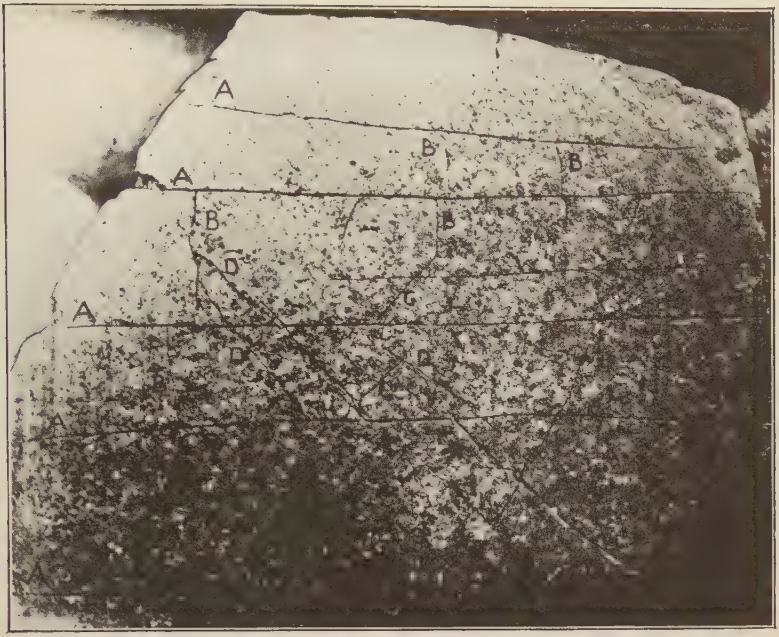

Fig. 3.—Horizontal Jointing in Basalt.

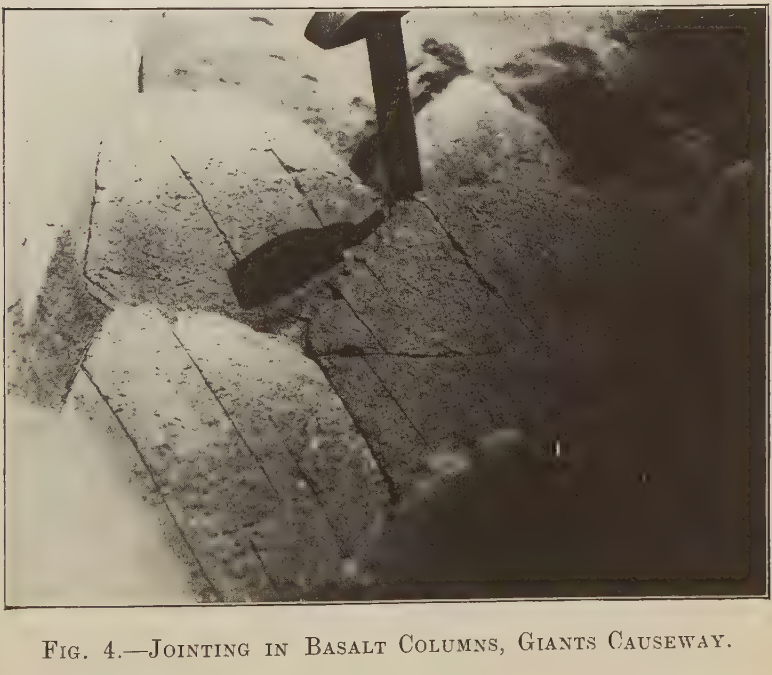

Fig. 4.—Jointing in Basalt Columns, Giants Causeway.

The whole appearance reminds one of the principles which Professor Hans Cloos (Bonn) has taught during the last few years.

According to him, open cracks can only be produced parallel to the direction of greatest pressure; perpendicular to this direction is that of least pressure, where planes of fracture remain latent, or where only traces of the latter can be found. Thus one could compare the open cracks (A on Fig. 3) with the Q-joints of Cloos, the joints perpendicular to the latter (B on Fig. 3) with S and L of Cloos, and the diagonal joints (C and D on Fig. 3) with "Mohr'sche Linien". The angle between A and B is 92 degrees, between C and D 65 degrees, and the latter practically halves the former.

Cloos regards pressure as primary cause, which enables open cracks merely in the direction of pressure.

But in this case it seems more obvious to assume tension as primary cause, the consequence of which would be open cracks at right-angles to the direction of tension. In both cases the effects as such would be the same.

The independence of the joints from the formation of the columns is proved by the following facts:—

1. Plastic material permits dislocations of the smallest particles and yields by flowing in the direction of least pressure, whereas only consolidated material would cause planes of fracture.

2. The non-existence of any relationship between joints and edges of the columns (in many cases the joints find their continuation on the neighbouring column). Thus the basalt must have consolidated and the hexagon form of the columns finished before fractures could take place.

Now it is obvious that the directions of principal joints coincide with the two main directions of faulting in Ireland, which strike north-west—south-east and north-east—south-west. Coinciding with these directions are the majority of Tertiary basalt and dolerite dykes, a considerable number of which occur in the Giants Causeway district itself. Dykes are nothing else but the later infillings of pre-existing joints or fissures (caused by tension) with molten material. As the country rock of the basalt dykes is basalt itself, the formation of the dyke-fissures must have taken place during a period which is bounded by the extrusion of the great basalt masses (that is the younger series, after the formation of the interbasaltic bauxitic and lateritic material) as the beginning, and the intrusion of the dyke-sequence of basaltic material as the end. It is natural to place the origin of the system of joints on the surface of the columns in this phase of orogenetic movements. Although this phenomenon—strange to say—is only recognizable on the surface of a few columns (in a district of several hundred thousand basalt columns) probably under weathering agencies, it has to be considered as a new proof for Dr. John W. Evans' theory of regional tension.[1]

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[1] *Q.J.G.S.*, London, 1925, Anniversary Address, p. 1, xxx.

Marine Horizons in the Coal Measures of South Wales.[1]

By Emily Dix, M.Sc., and A. E. Trueman, D.Sc., F.G.S., University College of Swansea.

THE fossils of the Coal Measures of South Wales have probably not been studied so systematically or for so many years as those of certain coalfields of the north of England, and it is only within recent years that any marked progress has been made in their investigation; this is especially true of the marine fossils.

As early as 1858 G. P. Bevan published an account of marine fossils found in association with certain seams and beds of ironstone in the upper part of the Millstone Grit and the basal parts of the Coal Measures of Monmouthshire and East Glamorgan. A few years later (1861) J. W. Salter published a somewhat more extended account of fossils occurring in the ironstones of that area; this was intended " to commence a detailed inquiry, that promises to be of great interest to the palaeontologist, and of considerable importance to the practical miner " (R. I. Murchison in the notice of Salter, 1861), but no further work of this character was carried out in South Wales for over half a century (Robertson, 1927, p. 135).

MARINE HORIZONS NEAR THE BASE OF THE COAL MEASURES.

The most frequent of existing records of marine fossils in the Coal Measures of South Wales relate to the lower part of the Lower Coal Series in the eastern portion of the coalfield, where they occur mainly (1) at horizons just above the base of the Lower Coal Series; (2) just below the Darren Pins Ironstone; (3) above the Rhas-las or Bydylog Seam.

Near the base of the Lower Coal Series are several marine bands. Bevan recorded *Spirifer bisulcatus* over the Bottom Vein; Salter recorded *Myalina carinata* Sow. over the Blue Vein Ironstone of Ebbw Vale and *Modiola* sp. and ? *Edmondia* sp. over the Red Vein Ironstone[2] of Ebbw Vale and Beaufort. Further west at Dowlais, Mr. G. Roblings found a marine shell (? *Edmondia* sp. nov.) over the Gellideg Seam.[3] These horizons all occur in the lower part of the zone of *Carbonicola ovalis*, as determined by the non-marine shells (Davies and Trueman, 1927). Marine forms may occur at an approximately comparable horizon in Pembrokeshire (Strahan, 1914, p. 161).

At the next horizon, below the Darren Pins Ironstone, Salter recorded marine shells (*Spirifer bisulcatus* Sow. and *Productus scabriculus* Sow.) in the mine over the Engine Coal (Salter, 1861;

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[1] The substance of this paper was read before Section C of the British Association at Leeds, 1927.

[2] It should be noted that this is not the Red Vein of the west of the coalfield, referred to below.

[3] This specimen has been presented to the University College of Swansea.

p. 228). The succeeding Darren Pins Ironstone includes the non-marine fossils characteristic of the zone of *Anthracomya modiolaris*.[1]

Still higher in the sequence, marine fossils occur over the Rhas-las Coal, where they were recorded by both Bevan and Salter. Further west, at Llanbradach, Mr. A. Howell has recently found *Productus* sp. and *Spirifer* cf. *duplicicosta* above the Rhas-las (Howell, 1927, p. 338). Mr. G. Roblings informs us that he collected *Lingula* sp. at the same locality and horizon many years ago.

In the west of the coalfield, definite evidence of marine bands corresponding with these is wanting, unless the horizon noted by Professor O. T. Jones near Picton Point in Pembrokeshire (in Strahan, 1914, p. 193) is to be regarded as occurring within these measures; it is near or possibly some distance below the Timber Vein, which is presumed to be equivalent to the Rhas-las (George and Trueman, 1925, p. 414), and it may correspond with one or other of the two bands just referred to, but definite evidence is wanting. In the cores of boreholes at Cwmgorse, referred to below, thin shales, possibly of marine origin, were noted over the Big Vein and over the Brass Vein, but in the absence of typical marine fossils it is premature to suggest that these bands can be traced in that area (Davies, Dix, and Trueman, 1928, p. 90).

MARINE BANDS AT HIGHER HORIZONS IN THE LOWER COAL SERIES.

Above the horizons just referred to there has been little positive information concerning marine bands except in the region almost due north of Swansea. Here marine fossils were noted above the Red Vein by the officers of the Geological Survey (Strahan, 1907, p. 95), and this horizon has been traced for a few miles, to Cwmgorse, but at other localities non-marine fossils have been found above the corresponding seam (Davies and Trueman, 1927, p. 244).

Much new information about this and other marine horizons has been gained from the examination of the cores from two deep boreholes made in the Cwmgorse Valley, about one mile south of the village of Cwmgorse.[2] These represented more than 2,000 feet of measures from the base of the Pennant Series to the productive strata of the Lower Coal Series; in the upper part of the cores the Welsh Vein and Red Vein were the only seams of importance, and the measures above and below these horizons have rarely been exposed or penetrated, and have not previously been systematically examined. The cores afforded much new information concerning the sequence of non-marine shells, especially in the upper part of the zone of *Anthracomya pulchra*, and supplied evidence of well-marked marine horizons. An account of the succession, with details of the fauna and flora, has recently been published (Davies, Dix, and Trueman, 1928), and it will be sufficient here to summarize the characters of the marine strata and to indicate their position in relation to the sequence of non-marine shells.

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[1] Many of the specimens referred to by Salter are housed in the National Museum of Wales, and some were figured in a recent publication (North, 1926); for facilities for their examination we are indebted to Dr. F. J. North.

[2] We are indebted to Mr. D. Farr Davies, F.G.S., for the opportunity to examine these cores, and to Sir Alfred Cope and the directors of the Amalgamated Anthracite Collieries, Ltd., for permission to publish these results.

A group of strata including several marine bands, extending for nearly 300 feet above the Red Vein, has been named the Cwmgorse Marine Beds. These consist of bands of marine shale, with a rich marine fauna, interbedded with shales (containing diminutive specimens of *Anthracomya*) and sandstones. The Welsh Vein, which occurs in the middle of these strata, apparently represents a more prolonged interval of non-marine conditions, although *Lingula* sp. and other marine forms occur in the fireclays immediately under the seam. In the cores just above the Red Vein were non-marine shells (*Anthracomya* sp.) ; the first strata with marine fossils occurred some 30 feet higher, where a band with *Lingula* sp., *Orbiculoidea* sp., and fish scales was succeeded by a thicker series of shales with very abundant *Pterinopecten papyraceus* (J. Sow.), associated with *Lingula* cf. *mytiloides* (Sow.), *Posidoniella* cf. *laevis* Brown, *Nuculana* cf. *sharmanni* R. Eth. jun., *Loxonema acuta* (de Kon.), and a goniatite fragment. Non-marine shells were found very rarely in the succeeding measures, but *Lingula* sp., *Orbiculoidea* sp., and *Euestheria simoni* Pruvost occurred in the strata below the Welsh Vein.

Above that seam occurred small specimens of *Anthracomya* sp., while the succeeding beds contained *Lingula* sp. and ostracods (*Beyrichia arcuata* and *Carbonia* sp.), but there was no evidence that fully marine conditions were established, and in the overlying shales *Anthracomya* sp. again occurred. A similar alternation was noticed at several horizons above this, but at about 90 feet above the Welsh Vein a typically marine fauna occurred, with crinoid ossicles, a goniatite fragment (*cf. Glyphioceras phillipsii* Foord and Crick), *Loxonema* cf. *acuta* (de Kon.), *Productus* (*Buxtonia*) cf. *scabriculus* Martin, *Lingula* cf. *squamiformis* Phill., *Orbiculoidea nitida* Phill. and *Euphemus urei* Flem. ; immediately above were shales with *Lingula* sp., and ostracods, again followed by beds with *Anthracomya* sp., but another marine horizon, with a fairly abundant fauna, was found some 50 feet higher.

The Cwmgorse Marine Beds thus appear to represent a fairly extended period during which very small changes in level brought in marine conditions. They are the highest strata of the Zone of *Anthracomya pulchra*.

About 400 feet below the Cwmgorse Marine Beds occurred a second marine group ; this was much thinner than the one just described. A group of marine shales overlying a thin seam contained *Orthoceras asciculare* Brown, *Orbiculoidea* sp., *Lingula* sp. and *Euestheria simoni* Pruvost. Marine fossils were found at intervals in the succeeding

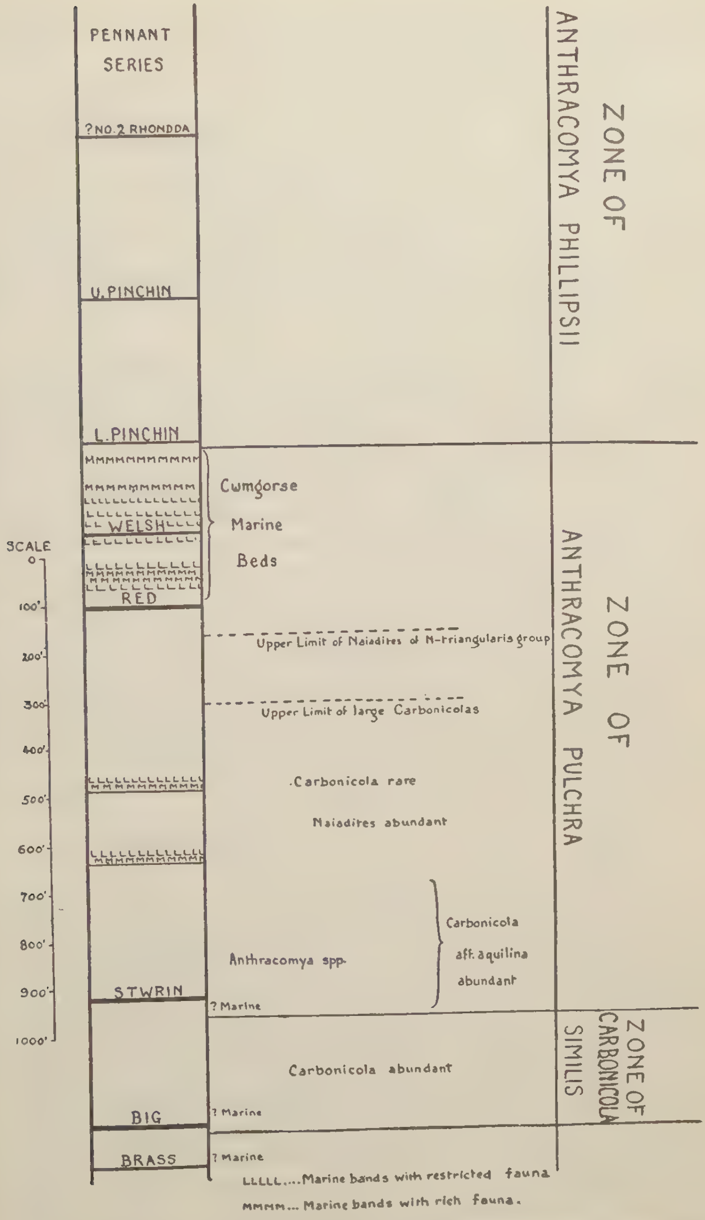
PENNANT SERIES
?NO. 2 RHONDDA
U. PINCHIN
L. PINCHIN
WELSH
RED
STWRIN
BIG
BRASS
SCALE
0
100'
200'
300'
400'
500'
600'
700'
800'
900'
1000'
Cwmgorse Marine Beds
Upper Limit of Naiadites of N-triangularis group
Upper Limit of large Carbonicolas
Carbonicola rare
Naiadites abundant
Anthracomya spp.
Carbonicola aff. aquilina abundant
? Marine
Carbonicola abundant
? Marine
? Marine
ZONE OF ANTHRACOMYA PHILLIPSII
ZONE OF ANTHRACOMYA PULCHRA
ZONE OF CARBONICOLA SIMILIS
LLLLL.... Marine bands with restricted fauna
MMMM... Marine bands with rich fauna.

Fig. 1.—Summary of the Faunal Succession in the Cwmgorse Boreholes, near Swansea. [The more important coal seams only are indicated.]

30 feet of shales, where *Euestheria simoni* was very abundant throughout. Less than 200 feet below this was a further band of similar character, not quite 20 feet in thickness.

Both of the latter marine bands occur in the measures near the middle of the Zone of *Anthracomya pulchra*. The distribution of non-marine shells in relation to the bands is indicated in Fig. 1; it may briefly be pointed out that typical specimens of *Naiadites* of the *N. triangularis* group were found to range up to just below the horizon of the Red Vein (that is, just below the base of the Cwmgorse Marine Beds), while large specimens of *Carbonicola* (*C.* cf. *aquilina* and *C.* cf. *fulva*) were very uncommon above the horizon of the lowest marine band, and none were observed for nearly 300 feet below the Cwmgorse Marine Beds.

The two higher marine groups discovered at Cwmgorse appear to represent widespread subsidences, and it is to be expected that corresponding marine strata will be found elsewhere in South Wales. The scarcity of records at present is largely to be explained by the fact that the associated measures are rarely penetrated as they contain few or no important seams in most parts of the coalfield. Recently Mr. A. Howell had recorded *Pterinopecten papyraceus* and *Lingula mytiloides* from the measures over the Gorllwyn Seam near the Navigation Colliery at Mountain Ash (Howell, 1927, pp. 352–3), and from the position of this seam it may be suggested that the equivalents of the Cwmgorse Marine Beds are to be looked for in the measures about that horizon. To the west there is no evidence of marine fossils in the Zone of *Anthracomya pulchra* except at Trimsaran in the Gwendraeth Valley, Carmarthenshire, where one of us (E. D.) has located a marine fauna between the Gregog and Drap Veins. It is not yet certain with which of the marine bands this horizon is to be correlated.

MARINE BANDS IN THE YORKSHIRE COALFIELD.

In the Coalfields of the Midlands and of the North of England the importance of marine bands has long been recognized, and the equivalents of certain horizons in North Staffordshire have been identified in Nottinghamshire, Derbyshire, and Yorkshire (Hind and Stobbs, 1905; Gibson, 1925, p. 58; Wilson, 1926). In the latter coalfield, in particular, the recognition of two marine bands at high horizons in the Middle Coal Measures has been of great assistance in the interpretation of borings. These two marine bands, which are known as the First or Top Marine Bed and the Mansfield Marine Bed, include a marine fauna which is practically identical with that of the marine bands in the Zone of *Anthracomya pulchra* at Cwmgorse, and they likewise occur in the middle and upper part of that zone.

In order to illustrate these facts a summary of the succession determined at the Maltby Colliery in Yorkshire is given in Figure 2 (partly after Wilson, 1926, p. 217); during the sinking of this

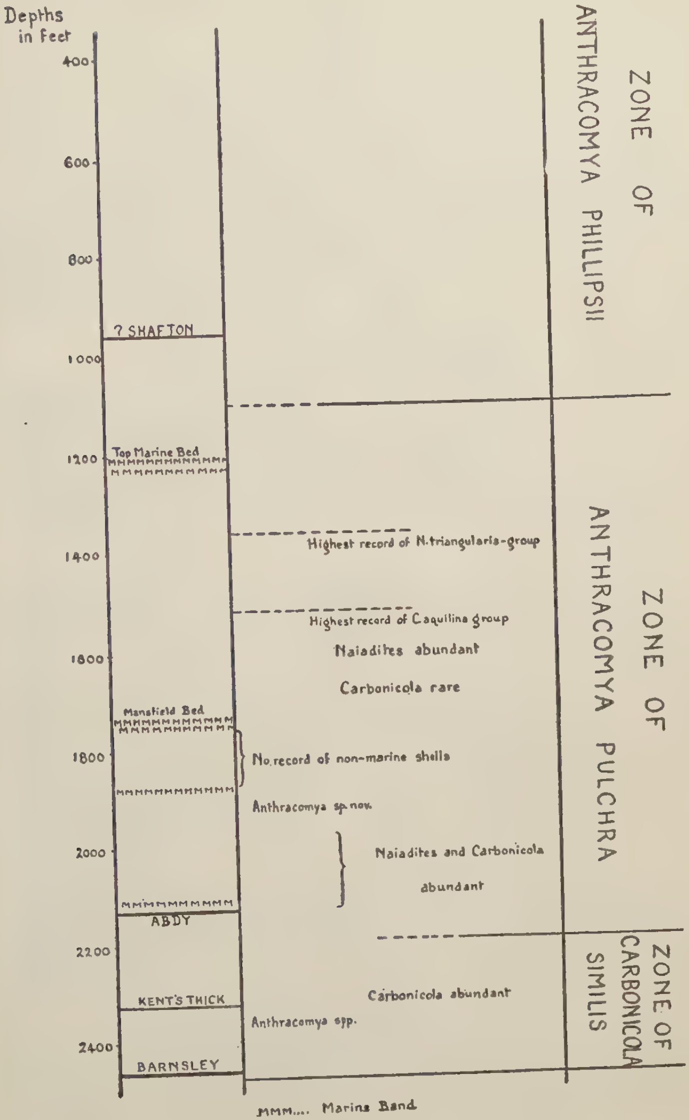

FIG. 2.—Summary of the Faunal Succession in the Coal Measures at Maltby Colliery, Yorkshire.

colliery Mr. W. Dyson made a systematic collection of fossils (Dyson, 1911), which is now housed in the Museum of Practical Geology. For access to this collection we are indebted to the authorities of that museum, and to Mr. J. Pringle for much advice and guidance. The non-marine shells in the collection were named by the late Dr. Wheelton Hind, but have been re-examined by the writers in the light of recent work (Davies and Trueman, 1927).

It will be noted that no specimens of *Naiadites* referred to the *N. triangularis* group were found above the Top Marine Bed, or for some distance below it, while large specimens of *Carbonicola* (*C.* aff. *aquilina* and *C.* cf. *fulva*) which were common for some distance above the Abdy Coal, were rare in the shales for 200 feet below the Mansfield Marine Bed, and above that horizon the highest record of that group occurring at 1,519 feet, almost half-way between the Mansfield and the Top Marine Bed.

There is thus a notable similarity in the sequence of non-marine shells in the two areas, the upper limits of these two groups (*N. triangularis* and *C.* aff. *aquilina*) occurring at corresponding horizons within the Zone of *Anthracomya pulchra*. Further, the lower part of the Zone of *Anthracomya phillipsii* is in each case characterized by small forms of *Anthracomya* of doubtful affinity, typical specimens of *Anthracomya phillipsii* occurring some hundreds of feet above the base of the zone.

If the sequence of non-marine shells in the two areas is taken as a basis for the correlation of the Coal Measures, it is notable that the Cwmgorse Marine Beds coincide in position with the Top Marine Bed (compare Davies and Trueman, 1927, p. 251), while the marine bed about 200 feet below the Red Vein at Cwmgorse coincides in position with the Mansfield Marine Bed. If the evidence of the non-marine shells were lacking any suggested correlation of marine bands in areas so widely separated as South Wales and Yorkshire would be extremely speculative, but in the present circumstances the facts appear to merit further investigation. It may be noted that in South Wales the Cwmgorse Marine Beds are thicker than the marine beds below, while in Yorkshire the Top Marine Bed is generally less notable than the Mansfield Marine Bed. On the other hand, the Top Marine Bed and the Mansfield Bed are only the more obvious bands, other less known marine beds being present in the associated strata; thus above the Shafton Coal Culpin recorded two horizons with marine fossils (1911, p. 610) while Mr. G. V. Wilson has pointed out that there are less important marine beds below both the Mansfield and Top Marine Beds. Mr. Wilson suggested that "the Coal Measures land surface was oscillating at about sea-level for a considerable period previous to the deposition of both the Mansfield and Top Marine Beds, and that each represents an important and fairly widespread incursion of the sea during Coal Measures times" (1927, p. 141).

Without suggesting that the evidence at present justifies any separate correlation of the various marine bands in South Wales and Yorkshire, the authors believe that a general correlation of the Cwmgorse Marine Beds and the measures for some 300 feet below with the strata ranging approximately from the Mansfield to the Top Marine Bed may be put forward ; more detailed correlation of the separate horizons within those measures must await more complete information. So far as South Wales and many parts of the North of England are concerned it may at least be considered as highly probable that during the time when the upper part of the Zone of *Anthracomya pulchra* was being deposited the whole of that area was more liable to invasion by the sea than was the case for some time previously, or afterwards.

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A Shelly Band in Graptolitic Shales.

By John Challinor, M.A., F.G.S.

IN the midst of a typically graptolitic development of the Valentian Series in Wales, a thin band containing a variety of shelly fossils has recently been noticed. It occurs in the Rheidol Gorge, Cardiganshire; part of the region described by Professor O. T. Jones in 1909 (1)[1]; the locality being that referred to by him as "F. 15", and the stratigraphical position 6 feet below the layer of calcareous nodules defining the top of the "*Triangulatus*-var.-band"; the shale band "2" in the table showing the beds of the zone of *Monograptus communis* as developed in the Rheidol Gorge (1, p. 488). Professor Jones refers to the presence of "fragments of *Orthoceras* or *Conularia*" at this locality. The band has an available outcrop of about 10 feet in length, and it was possible to examine it for some 2 or 3 feet in the direction of dip. It is about 3 inches thick and is not individualized in any way other than by its fossil contents; lithologically it is to all appearances the same as the rest of the dark-blue iron-stained shales in which it occurs.

Graptolites are abundant and well preserved in the shales immediately above and below, and also occur in the shelly band itself; these graptolites are not further alluded to in this paper. Except for fragments of *Orthoceras*, the fossil shells are rather rare. An intensive search has resulted in the finding of the following: Brachiopoda; four separate shell-valves of the genus *Lingula*, two of one species and two of another. Pelecypoda; fossils of seven individuals, mostly quite unlike one another, belonging to seven species. Gastropoda; one individual of the genus *Pterotheca* and three individuals of the genus *Hyolithes*, probably more than one species. These genera belong to the group Pteropoda. Cephalopoda; numerous fragments of the genus *Orthoceras*, belonging to three or four species.

It will be seen that there is considerable variety, as nearly every individual (except those of *Orthoceras*) is a distinct form, and they are distributed amongst four well-differentiated zoological groups. Probably all the animals were thin-shelled; the general appearance of the fossils suggests this, and it is to be expected as the explanation of their having lived in a common environment, and being fossilized as aliens in the foreign graptolitic facies.

The following are some notes on the specimens, which are deposited in the Department of Geology, University College of Wales, Aberystwyth (the serial numbers refer to the general fossil collection). Most of them were brought to light by the skilful collecting of Mr. A. R. Sansbury, a student of the College. I am also very greatly indebted to Mr. John Pringle for his most kind and valuable assistance in the identification of the pelecypods.

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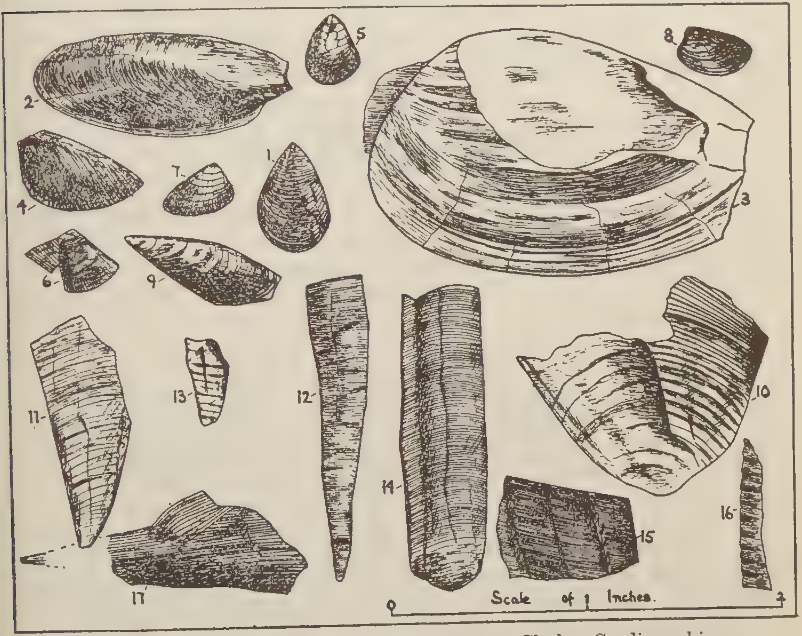
[1] See the list of references at the end of this paper.

BRACHIOPODA.

Lingula attenuata Sowerby (10653A, Fig. 1).

The specimen shows casts of the external surfaces of two shell-valves belonging (apparently) to two individuals. The cast figured is complete, the other shows about half the surface. They may be referred without much doubt to this species, agreeing well with J. de C. Sowerby's original figure (2, pl. 22, fig. 13) but more particularly with some of Davidson's figures (3, vol. iii, pl. iii, figs. 19–21).



FIGS. 1–17.—Shelly Fossils from Graptolitic Shales, Cardiganshire.

This species is considered to be confined to the Llandeilo Series, though Phillips records it in the Llandovery Series ("Upper Caradoc") of Malvern (4, p. 275). Reed describes and figures various species of *Lingula* from Girvan; one of these, *L. amabilis* Reed, contains some forms previously referred to *L. attenuata*, the horizon being, however, the Balclatchie Group of the Ordovician (5, p. 803, pl. ii, figs. 3–8). All Reed's Girvan species are from the Ordovician except *L. symondsi* Salter, of which the occurrence there, in the Llandovery, is "tolerably certain". The present individuals bear some resemblance to some of Davidson's figures of this species (3, vol. iii, pl. iii, figs. 9, 10). Portlock (6, p. 443) records *L. attenuata* from Silurian "dark slatey flags" (probably Valentian) from the Pomeroy district of Tyrone.

Lingula bechei Salter (10581–10584, Fig. 2).

The specimens are external moulds and casts of external surfaces. There are two valves lying near together in the rock, but one the reverse way (longitudinally) to the other, so that they probably belong to two individuals. One of the casts is figured, but the sketch does not show adequately the regularity of the numerous fine concentric lines. The fossils are evidently compressed sideways so as to be more convex than is natural, and are incomplete. Nevertheless they appear to be undoubtedly *Lingulae* and may be referred with confidence to this species, agreeing well with Davidson's figures (3, vol. iii, pl. iii, figs. 12, 13) and still more decidedly with his actual types in the Geological Survey Museum. This is a Llandovery pecies.

PELECYPODA.

Indeterminate (10592, Fig. 3).

The specimen represents the greater part of the left valve (and possibly a part of the other valve squashed into a position at the anterior end of this valve) of a striking pelecypod, but one which I have been unable to identify even so far as the genus. It is much larger than any of the other pelecypods found. The fossil is the cast of the external surface.

Dualina elegans (Salter) (10586, 10587, Fig. 4).

The specimen figured (10586) is the cast of the external surface of one valve, the other specimen being the corresponding external mould. It is the left valve of a distinctive form, markedly convex with well-defined radial striae. Salter figures the shell as *Lunulacardium elegans* (7, p. 139, pl. ii, fig. 10). Mr. Pringle writes as follows, from the Geological Survey Museum, about this fossil: " Salter's figure is a poor one and the shell is from the Upper Ludlow. In this museum we have specimens from the Wenlock Shale and your shell is identical with them ". In his description, Salter makes the remark " The shell is very thin ".

Pterinea sp. (10589, Fig. 5).

This is a small poorly-preserved fossil. Mr. Pringle places it in the genus *Pterinea*. It represents a left valve and may be the internal mould or the cast of the external surface.

Cf. *Pterinea* sp. (10637, Fig. 6).

This is also a small poorly-preserved fossil, but suggests the genus *Pterinea*. It also has some features which suggest the species *Slava fibrosa* (Sow.). It is a cast of the external surface of the (?) right valve.

Indeterminate (10588, 10585, Fig. 7).

This small fossil is distinctive in shape and ornamentation but is not easily referable to any known form. Mr. Pringle suggests

Slava or *Cardiola* as possible genera. The specimen figured (10588) is the cast of the external surface of the right valve, the other specimen being the corresponding external mould.

Cf. *Edmondia simplex* Hind (10590, Fig. 8).

This again is a distinctive little shell but as yet indeterminable with any degree of certainty. The nearest resemblance I have been able to find is Hind's Girvan form as above (8, pl. v, fig. 5). It is an external mould of the right valve.

Cf. *Modiola brycei* Portlock (10591, Fig. 9).

This shell is much distorted but is tentatively referred to this species described by Portlock (6, p. 425, pl. xxxiii, fig. 7). He gives the Pomeroy (Desertcreat) district as the locality, and the horizon is probably in the Valentian. He refers (6, p. 231) to the rare occurrence of " a Mytilus " in shales containing " Graptolithus Sedgwickii." Fearnsides, Elles, and Smith (9, p. 109) also refer to the occurrence of pelecypods in " somewhat calcareous " beds among the graptolite-bearing mudstones of this zone in this locality. The fossil is the cast of the external surface of the left valve.

GASTROPODA (*Pteropoda*).

Pterotheca sp. (10641, Fig. 10).

The specimen may be placed with confidence in Salter's genus *Pterotheca*, but it is impossible to suggest any particular species. It is an external mould.

Hyolithes sp. (10648, 10649, Fig. 11).

The individual may certainly be placed in Eichwald's genus *Hyolithes*, and resembles several of the species described (as new) by Reed from Girvan (10), but cannot be definitely referred to any one of them. Most of Reed's specimens are from the Ordovician, but species of *Hyolithes* (and *Pterotheca*) are described from the Valentian.

Cf. *Hyolithes* sp. (10606, 10633, Fig. 12).

The individual probably belongs to this genus, but is not unlike some figures of *Orthoceras* (cf. *O. incertum* Portlock; 6, pl. xxviii, fig. 1).

Cf. *Hyolithes* sp. (10635, 10607, Fig. 13).

This is another distinct form probably referable to the same genus.

Each of the above three forms are represented by two fossil specimens, one being the cast of the external surface of one side and the other the corresponding external mould. The specimens figured are numbers 10648, 10606, and 10635, the first two being casts and the third a mould.

CEPHALOPODA.

Orthoceras cf. *araneosum* Barrande (numerous specimens, Fig. 14).

Specimen 10601, a cast of part of the external surface, is figured. There are numerous similar fragments and they all appear to belong to this species.

Orthoceras sp. (several specimens, Fig. 15).

Specimen 10614, an external mould, is figured. Several of the fossils of *Orthoceras* are wider and have the transverse striae closer together than in the case of those referred to the first species.

Orthoceras cf. *annulatum* Sowerby (several specimens, Fig. 16).

Specimen 10595, a cast of part of the external surface, is figured.

Cf. *Orthoceras* sp. (10608, Fig. 17).

The strong longitudinal striations and absence of transverse striations mark off this specimen from all the others found. It is the cast of part of the external surface.

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Notes on the Middle and Upper Chalk of the Cambridge District.

By A. G. BRIGHTON, M.A., F.G.S., Sedgwick Museum, Cambridge.

OF the more recent accounts of the Middle and Upper Chalk of Cambridge, only that of Jukes-Browne[1] employs the definitions of zonal boundaries now usually accepted in England; for the most part, the horizons to which he refers the exposures are correct.

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[1] A. J. Jukes-Browne, 1903–4, "The Cretaceous Rocks of Britain," vols. ii, iii, *Mem. Geol. Surv.*

The only major criticism which can be made is that he has confused together, as Chalk Rock, two series of nodular Chalk which occur in Cambridge, the lower (the true Chalk Rock) in the lower part of the *Planus* Zone, the upper (the Top Rock) in the lower part of the *Cortestudinarium* Zone. Since the pits are for the most part now but rarely worked, the details he gives of the sections remain accurate, and although his faunal lists could be largely extended, his description is still the most useful. The accounts by Professor Fearnsides and Dr. Rastall[1] are more of the nature of summaries, and they interpret their "zone of *Holaster planus*" to include what would now be called the upper part of the *Terebratulina* Zone. The following notes are intended to be complementary to Jukes-Browne's account, to which reference should be made for details of the sections.

Terebratulina Zone.—The pits mentioned by Fearnsides (op. cit., p. 34) as belonging to the lower part of the *Planus* Zone have all yielded *Micraster corbovis* of the *Terebratulina* Zone type and belong to that horizon. The pit by the road-side half a mile east of Great Chesterford Church, Essex (Jukes-Browne, op. cit., vol. ii, p. 470) is especially interesting. It shows about 50 feet of white chalk, with a prominent 6 inch marl band in the lower half. Below the marl band, I have collected in situ *Micraster corbovis* Forbes, *Sternotaxis planus* (Mantell),[2] *Echinocorys scutatus* Leske var. nov. aff. *gravesi* Desor, *Inoceramus lamarcki* Parkinson, and *Terebratulina lata* Etheridge. The thirty examples of *M. corbovis* which I have examined from this pit are all typical *Terebratulina* Zone forms: no specimens of *M. leskei* or *M. praecursor* have been found. There is thus no doubt that the pit exposes the *Terebratulina* Zone. The occurrence of *Echinocorys* (the appearance of which can usually be taken as proving the base of the *Planus* Zone) is therefore interesting. The eight examples in my possession are all imperfect: although exhibiting novel features, they agree in the relatively high position of the ambitus with the "gibbous" form shown by Rowe to be the typical form of *Echinocorys* in the *Planus* and *Cortestudinarium* Zones, and identified by M. Lambert as *E. gravesi* Desor.[3] There is insufficient material as yet to discuss the relation between this new form and its apparent ancestor *Holaster rotundus* Jukes-Browne,[1] a question which I hope to investigate in the future.

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[1] W. G. Fearnsides, 1904, "Geology," in Marr and Shipley, *Natural History of Cambridgeshire*, 8vo, Cambridge. R. H. Rastall, 1910, "Cambridgeshire, Bedfordshire, and West Norfolk," chap. v, in *Geology in the Field*, Jubilee volume of the Geologists' Association, 8vo, London.

[2] The form usually known as *Holaster planus* (Mantell). M. Lambert (1893, *Bull. Soc. Sci. Yonne*, xlvii, p. 41) erected for this species the genus *Sternotaxis*, which differs essentially from *Holaster* in the composition of the plastron. It is unfortunate that the name of a well-established index-fossil should have to be changed; but the awkwardness may in part be overcome by adopting the Geological Survey practice of referring to zones by the trivial name of their index-fossil.

[3] A. W. Rowe, 1908, *Proc. Geol. Assoc.*, xx, p. 301 (*inter alia*). J. Lambert, 1903, *Mém. Musée Roy. Hist. Nat. Belgique*, ii, p. 48.

Planus Zone.—Although the statement (Fearnsides, op. cit.) that the *Planus* Zone includes much Chalk below the Chalk Rock is based on an interpretation of the zonal limit different to that now usually accepted, it is at least possible that the Chalk Rock in Cambridge occurs slightly above the base of the *Planus* Zone, as Mr. Dixon Hewitt has shown to be the case round Thetford (1924, *Proc. Geol. Assoc.*, xxxv, pp. 220–44). All the specimens of *Micraster* which I have obtained throughout the whole thickness of Chalk Rock at Underwood Hall (Jukes-Browne, op. cit., iii, p. 238) are forms characteristic of the lower part of the *Planus* Zone. The beds beneath the Chalk Rock are not very fossiliferous; but I have seen a specimen of the *Micraster leskei-praecursor* passage form, said to come from below the lower tabular flint beneath the Chalk Rock, which would, if authentic, prove the extension of the *Planus* Zone below the Chalk Rock as here developed.

The most prolific exposure in the *Planus* Zone above the Chalk Rock is that at the road fork three-quarters of a mile slightly north-of-west of Weston Colville Church; specimens of *Micraster* from the lowest 7 feet in this pit are characteristic of the upper part of the *Planus* Zone. The few specimens found at higher levels indicate the near approach to the top of the zone.

Echinocorys scutatus is by no means a common fossil in the *Planus* Zone of this district.

Cortestudinarium Zone; Top Rock.—In the district south and south-west of Newmarket, the Top Rock and the Chalk Rock are distinct in lithology. As seen at Underwood Hall, the Chalk Rock is yellow and nodular, sometimes hard and siliceous, sometimes soft and powdery, in ill-defined bands alternating with more normal chalk; the characteristic fauna (Woods, 1896–7, "Mollusca of the Chalk Rock," *Q.J.G.S.*, vol. lii, pp. 68–98; liii, pp. 377–403) is well represented. As exposed in the pit three-quarters of a mile south-west of Westley Waterless (Jukes-Browne, op. cit., iii, p. 237), the Top Rock consists of a hard limestone with pinkish-brown nodules; the upper portion is crowded with many green-coated nodules and the top is quite definite; the rock is about 1 foot thick, and passes gradually into normal Chalk below. It is not very fossiliferous; repeated visits have yielded only *Sternotaxis placenta* (Agassiz). Mr. T. N. George has, however, obtained *Martesia ? rotunda* (J. de C. Sowerby)—showing that typical Chalk Rock lamellibranchs do occur—and Mr. G. B. Alexander has found specimens of *M. praecursor* typical of the lower part of the *Cortestudinarium* Zone. The bed therefore represents the Top Rock, which has now been recognized over wide areas[1] at or about the junction of the *Planus* and *Cortestudinarium* Zones. The similar bed at Wood Ditton (Jukes-Browne, op. cit., iii, p. 238) has also yielded specimens of *Micraster* typical of the lower part of the *Cortestudinarium* Zone. Here, however, green-coated nodules also occur at the base of the soft white Chalk immediately overlying the rock-band. The appearance of the section is complicated by cavities overlying the rock-band (due probably to solution, the rock-band being impervious); some of the cavities have collapsed, so that lenses of much broken Chalk, contaminated with material deposited by percolating water, rest in places on the rock-band. The lowest horizon exposed in the pit has yielded specimens of *Micraster corbovis* typical of the *Planus* Zone; and a *Planus* Zone *Micraster praecursor* has been collected 3 feet below the tabular flint.

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[1] Afterwards identified by Jukes-Browne (1903, op. cit., ii, p. 18) as *Offaster sphaericus* Schlüter, and used under that name as the index-fossil of the Upper Cenomanian of Yorkshire.

The pit half a mile north-west of West Wratting has yielded *Micraster praecursor* typical of the *Cortestudinarium* Zone. Specimens of *Echinocorys scutatus* are not uncommon; the six examples I have seen are all very thin-shelled forms.[2]

My thanks are due to many students of Cambridge University, who have not only searched in the more barren of these exposures, but also presented to the Sedgwick Museum the most important of the specimens they have found.

On a Custerite-bearing Contact Rock from California.

By C. E. Tilley.

THE mineral custerite $[Ca(F,OH)]_2SiO_3$ was first described from a limestone contact rock from Custer, Co. Idaho, the associated minerals being diopside, garnet, and magnetite. There appears to be no further record of this mineral from contact zones, though the related cuspidine $[CaF]_2SiO_3$ is known from Vesuvius and Franklin Furnace. In examining some metamorphosed limestones from the well-known mineral locality of Crestmore, California, the writer has found that custerite occurs in a vesuvianite rock in some abundance. As the mineral associations of this custerite are different from that of the original custerite, and owing to the very rare occurrence of this mineral, it is deemed of sufficient interest to describe this association briefly. The rock consists largely of idioblastic vesuvianite, these crystals being cemented together by a light brown base which proves to consist almost entirely of custerite, monticellite, and calcite. The custerite forms comparatively large shapeless areas enclosing subidioblastic crystals of monticellite. Under the microscope the custerite is seen to be colourless with a distinct cleavage, parallel to which lamellar twinning is developed. Sections cut perpendicular to the twin lamellae show symmetrical extinction of 6°.

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[1] See, for instance, Dixon Hewitt, 1924, op. cit., p. 226; and "Geology of the country around Dartford," 1924, *Mem. Geol. Survey*, p. 24.

[2] Jukes-Browne (op. cit., iii, p. 237) records, apparently from this pit, specimens characteristic of the *Planus* Zone; further, there is a *Planus* Zone type of *M. corbovis* preserved in the Sedgwick Museum, and labelled "N.W. of West Wratting". It is possible that the Top Rock and part of the *Planus* zone were once exposed in parts of this pit which are now filled in.

The mineral is clearly monoclinic, optically positive, Z being approximately normal to the twinning lamellae, and the obtuse bisectrix emerges from sections cut normal to the lamellae. If the important cleavage is taken as 001, the orientation is $X = b$, $Y \wedge 001 = 6°$. The refraction determined by immersion liquids is $\alpha = 1{\cdot}588$ $\gamma = 1{\cdot}600$ $\Delta = {\cdot}012$. These data correspond with those for the custerite of Idaho and the optical orientation distinguishes the mineral from cuspidine.

Monticellite is a constituent of other assemblages from the Crestmore locality as already recorded by Eakle. It is clearly the mineral A described by Foshag and Larsen in the merwinite rock from this locality. A specimen of this rock sectioned was found to contain merwinite, monticellite, gehlenite, spurrite, grossular, and vesuvianite. Merwinite has so far been recorded only from Crestmore and from Larne (Ireland). It is therefore of interest to note that it also occurs as a constituent of a spurrite rock from Velardeña, Mexico, from where spurrite was first described. In the rock examined from this locality the spurrite was found associated with grossular, vesuvianite, gehlenite, and merwinite.

It can scarcely be doubted that the occurrences of these rare minerals are the consequence of incomplete equilibrium during metamorphism. In normal contact aureoles they are represented by the more common assemblages of similar bulk-chemical composition. Apart from being petrological curiosities, they are perhaps of interest as exemplifying an arrested stage in the establishment of equilibrium.

REVIEWS.

Brachiopod Morphology and Genera (Recent and Tertiary). By J. Allan Thomson. pp. vi + 338 + 2 plates. Ex. cr. 8vo. (New Zealand Board of Science and Art, Manual No. 7.) Wellington, N.Z.: Government Printer; London: High Commissioner for New Zealand; 1927. Price 17*s*.

DR. THOMSON'S researches on brachiopod morphology during recent years have been followed with great interest, and the summarizing of the results obtained by himself and other workers is very welcome. The volume just published is of convenient size and replete with figures of structural details taken from Dr. Thomson's own papers and from the works of many other noted brachiopodologists. There is a copious bibliography of papers and memoirs dealing with the various branches of the subject. This is usefully divided into a main list and lists of the Tertiary Brachiopods of different geographical areas. There is also an index of technical terms and one of systematic names.

The early part of the work is devoted to brachiopod morphology and the later part to the description of brachiopod genera (Recent and Tertiary). The work reveals in a striking manner the considerable advances that have been made since the publication of Davidson's famous monograph in 1886–8. In the major classification of the class, Dr. Thomson introduces two new subclass names, Gastrocaulia and Pygocaulia, these being approximately equivalent to the older Inarticulata and Articulata of Huxley. The reasons for this new classification, which is based upon the genesis of the pedicle rather than upon the presence or absence of articulation, are clearly stated and a full discussion of Beecher's and Schuchert's views is given. The new arrangement has necessitated certain emendations of Beecher's orders Atremata and Neotremata forming the subclass Gastrocaulia, and the creation of a new order Palaeotremata (for Rustellacea and Kutorginacea) which is included in the subclass Pygocaulia with the Protremata and Telotremata of Beecher. In addition to the above, one new superfamily, Paterinacea, two new subfamilies, Platidiinae and Laqueinae, and eight new genera are created.

In dealing with the anatomy, the researches of Morse, Blochmann, and Yatsu, among others, are fully utilized. The types and the development of the lophophore are based on Beecher and his account is closely followed and his figures reproduced. The spiculation of the mantle and other parts is briefly dealt with and, though the functions of the spicules are not yet well known, it is pointed out that the presence or absence of these bodies may be of help in establishing the relationships of genera and species. Dr. Thomson has found the presence or absence of strong spiculation a useful guide in differentiating the subfamilies of the Terebratellidae.

There is an interesting chapter on development and the embryological studies (especially of *Lingula*, discinids, *Argyrotheca*, *Lacazella*, and *Terebratulina*) of a large number of workers are fully discussed and numerous illustrations reproduced. These studies have an important bearing upon the distribution of the Brachiopoda. The available facts indicate that the power of distribution is very limited, but definite conclusions as to the duration of the free-swimming stages cannot be established until more is known of the larvae and the time of fixation in a larger and more varied series of genera. Lingulids and Discinids seem to differ from the rest of the class in that they have greater capacity of distribution both from the length of the free-swimming stage and their liability to be transported over deep oceans in surface currents. But even here controlling factors appear to be present which restrict the geographical range of certain species. In the Discinidae the free-swimming stages seem to be shorter than in *Lingula* and *Glottidia*, and the known facts indicate that Schuchert's statement (1911) that the larvae "are known to live in the free and floating condition for nearly a month" is probably an overstatement. Observations on *Terebratulina* show that the young settle down after ten or twelve days; they do not seem to be pelagic, and are not found in the plankton.

Another interesting chapter deals with the morphology of the brachiopod shell and in the paragraphs concerned with the development of the outline two new technical terms are introduced, viz. mixoperipheral growth and palintrope. The first may be regarded as a special form of holoperipheral growth of Beecher and consists of successive bands of new shell-matter being added in the usual way to the lateral and anterior margins of the shell, but on the posterior margin the bands are added in such a way that a reversal of the direction of facing of this part of the outer surface takes place and a palintrope is formed. In the paragraphs dealing with types of cardinal margin and of folding Buckman's treatment is closely followed. The morphology of the pedicle-opening and beak then follows, and here it has been found necessary to make use of many early forms (Cambrian onwards) in order to illustrate development fully. Some modifications are not yet clearly traced. In the case of the Telotremata, Buckman's researches have again been drawn upon as giving great precision to a description of these features. But it is pointed out that in fossil Rhynchonelloids and Terebratuloids many more species require re-examination before precise comparisons can be made.

The internal morphology of the valves is described in a concise and lucid manner and the paragraphs on articulation, cardinalia, brachidia, and muscular impressions contain some interesting details illustrated by figures.

In connection with the composition and structure of brachiopod shells, Dr. Thomson discusses the views of various authors with regard to phylogeny. There is much diversity of opinion here and further studies are desirable, especially of early Palaeozoic calcareous shells. After reviewing what is already known of the composition and structure of the shells of various genera, Dr. Thomson gives a tentative arrangement of the various stages passed through.

The second part of Dr. Thomson's treatise opens with some useful remarks on the conception of the genus and then follow the descriptions of the Brachiopod genera (Recent and Tertiary). This account includes particulars of all ascertainable morphological characters considered useful for the classification of doubtful species. References are given to the literature of the genotypes, most of which are illustrated. A list of species (Tertiary to Recent) and copious remarks follow the description of each genus. The eight new genera all belong to the order Telotremata: one (*Hispanirhynchia*) belongs to the Rhynchonellidae, one (*Abyssothyris*) to the Terebratulidae, and six (*Japanithyris, Jaffaia, Pictothyris, Neobouchardia, Pirothyris*, and *Malleia*) to the Terebratellidae. Some of the species, however, included under certain genera are obviously not in their proper place; they certainly represent further new genera.

The revision of the Terebratellidae and especially of the subfamily Magellaniinae is largely due to Dr. Thomson's excellent work on the large amount of New Zealand Tertiary material which he has had through his hands in recent years. Some portion of this work and the description of new genera was published in the Geological Magazine and will be familiar to readers.

The death of Dr. Thomson so soon after the publication of this excellent work is deeply to be regretted.

J. Wilfrid Jackson.

Catalogue of the Rock Collections in the Mineral Department of the British Museum (Natural History). Arranged Geographically. Part I: Africa. By W. Campbell Smith, M.C., M.A., F.G.S., Assistant-Keeper in the Mineral Department of the British Museum. London, 1928. Price 2*s*.

THE collections of rock specimens at the Natural History Museum are arranged both on a systematic and a topographical basis. The publication of Part I of the catalogue of the Topographical Collection will be useful to geologists and petrologists since it shows the wealth of material available for reference and study in the Department. The catalogue will be printed in parts, the continental and oceanic areas being issued in alphabetical order.

In the introduction Colonel Campbell Smith gives an interesting historical account of the growth of the rock collections, from which the following particulars are extracted. The first notable acquisition was in 1823, when Dr. Monticelli's collection of volcanic rocks from Vesuvius and the Phlegraean Fields was purchased. In 1876 Professor Judd presented some 600 specimens of volcanic rocks from Hungary and the Lipari Islands. In 1877 the Museum purchased Samuel Allport's collection of British rocks, containing some 2,000 specimens, together with thin sections for the microscope. In the same year 4,500 specimens were transferred from the Indian Museum, and an important addition was made in 1911, when the foreign collections which had accumulated in the Museum of the Geological Society of London during the past hundred years were transferred. This collection of over 10,000 specimens included important gifts from foreign geologists, such as H. Von Dechen, F. S. Beudant, and Count Bournon, and also included the collections illustrative of the papers read by many Fellows of the Geological Society, among which may be mentioned G. P. Scrope's work on the Auvergne and G. W. Stow's papers on South Africa.

Valuable additions have been made by the presentation of the collections of the various Arctic and Antarctic expeditions, terminating in the voyages of Scott in the *Terra Nova* and of Shackleton in the *Quest*. The *Challenger* expedition of 1873–6 also contributed.

The part now published gives particulars of the collections of rocks from the following countries: Algeria, Morocco, Libya, Egypt, Abyssinia, Eritrea, British Somaliland, Socotra, Anglo-Egyptian Sudan, French West Africa, French Guinea, Sierra Leone, Gold Coast, Nigeria, Cameroons, French Equatorial Africa, Belgian Congo, Uganda, Kenya Colony, Tanganyika Territory, Portuguese East Africa, Nyasaland Protectorate, Northern Rhodesia, Angola, South-West Africa, Bechuanaland Protectorate, Southern Rhodesia, Transvaal, Swaziland, Natal and Zululand, Orange Free State, Cape Province, and Madagascar.

The particulars under each head give a brief description of the collection, the method and date of acquisition, the collector and the size of the collection. A valuable possession are representative specimens of the cores of important deep boreholes, such as the set from a number of boreholes put down under the supervision of the present writer to prove the existence of a concealed syncline of the Witwatersrand Beds in the Far East Rand.

It is perhaps worth while pointing out that on page 38 borehole cores from 200–3,000 feet in a borehole drilled in 1904 at Barrett's Rietfontein, are erroneously described as coming from Kimberley instead of from the East Rand.

There is an Index of Persons (Donors, Collectors and Authors), one of Localities, and one of Rock Names, Geographical Formations, etc.

F. H. Hatch.

WELLS AND SPRINGS OF SOMERSET. By L. RICHARDSON. Mem. Geol. Survey England. pp. v + 279, with a coloured geological map and 3 text-figures, 1928. Price 7*s.* 6*d.*

WE welcome the appearance of another volume of this valuable series, dealing with one of the largest counties of England, whose geological structure presents many points of very special interest. The up-to-date coloured map on the scale of 4 miles to an inch will be very useful, since, as pointed out in the preface, many of the one-inch maps of the county are much in need of revision. The memoir contains the usual wealth of detail as to water-supply and cognate subjects, with a brief summary of the geological formations represented. It is perhaps rather surprising that, so far as the reviewer can discover, the actual descriptive matter relating to the hot springs of Bath amounts to about four lines, although several pages are devoted to a copious bibliography of the subject, compiled by the late Mr. Whitaker.

R. H. R.

CONTRIBUTION À LA GÉOLOGIE DES VOSGES HERCYNIENNES D'ALSACE. By J. Jung. Mém. Service Carte Géol. d'Alsace et de Lorraine. pp. 481, with 5 plates, 2 coloured maps and 22 figs. Strasbourg, 1928.

THIS large and well-printed volume contains the results of a detailed study of the rocks and structures of the Vosges, with special reference to their relation to the Hercynian fold-system. All the rocks up to the base of the Trias are very fully described, and show some noteworthy features. For English readers the most interesting part of the work is the discussion of the tectonic events in this area during the Carboniferous and Permian. The author maintains, as a result of his careful study of the distribution of facies and isopic zones in the Devonian and Carboniferous, that the usually accepted opinion, that the Vosges and the Central Plateau of France belonged to the Mediterranean geosynclinal, in untenable. There are clear proofs of a Hercynian geanticlinal separating the geosynclinal of the Ardennes and Northern France from the Mediterranean region, which made its presence felt even in the Lower Palaeozoic by shallows, with a littoral facies of sedimentation preceding the Devonian transgression, traceable from Brittany to Moravia. The maximum uplift of this geanticlinal took place at the end of the Dinantian, accompanied by granite intrusions. The Franco-Belgian coal-basin was a rubbish-shoot in front of the chain ; after being filled up this area also was folded and overthrust in the well-known way, but the main point appears to be that the Hercynian structures of the Vosges belong to the earlier, Lower Carboniferous, phase.

REPORTS AND PROCEEDINGS.

Glasgow Geological Society.

12*th April*, 1928.

Dr. G. W. Tyrrell: "Recent Scottish Earthquakes."

Three principal and several minor shocks were described. The main earthquakes were:—

(1) The Oban earthquake of 23rd December, 1925. 12.35 p.m.
(2) The North Sea earthquake of 24th January, 1927. 5.20 a.m.
(3) The Colintraive earthquake of 27th January, 1927. 9.3 a.m.

The Oban earthquake reached an intensity of about 6 on the Rossi-Forel scale in a small area between Oban and Tobermory, but was felt over a very large area extending from Banffshire to Ayrshire. The isoseismals are elongated in a N.E. to S.W. direction, and the quake appears to have been due to movement along the Great Glen Fault near the intersection of Loch Linnhe with the Sound of Mull. An interesting sympathetic shock took place near Bothwell, Lanarkshire.

The North Sea earthquake was a considerable shock which was felt over practically the whole of Scotland, and part of the North of England, and was also felt over the greater part of southern Norway. Phenomena indicating intensity 6 on the Rossi-Forel scale were experienced in Aberdeenshire and neighbouring counties. In Peterhead and Aberdeen the overthrow of movable objects occurred to some extent, and it is probable that the isoseismal 7 skirted the coast. Isoseismal 6 runs from Montrose through Nairn, and then in a north-easterly direction east of the Caithness coast, the Orkneys, and the Shetlands. This earthquake is still under investigation on both sides of the North Sea, and Dr. Niels Henry Kolderup is collecting the Norwegian records. It is probable that it was due to movement along a fault under the North Sea some distance to the west of Haugesund, Norway.

The Colintraive earthquake, three days later, reached an intensity of 5 in a small area centring about Colintraive on the eastern Kyle of Bute. To the S.E. it was felt as far as Ecclefechan, Dumfriesshire. The isoseismals are elongated in a N.W. to S.E. direction, and the isoseismal axis runs along the eastern Kyle of Bute to Loch Gilp. An after shock which reached an intensity of 4 in an area elongated N.E. to S.W. along Loch Fyne and West Loch Tarbert occurred at 4.10 p.m. on the same day. These earthquakes seem to be due to movement in the rectangular network of fiord fissures in the region shaken.

Dr. J. F. Scott: (*a*) "Composite Dyke, Havock, Dumbartonshire"; (*b*) "The Plutonic Intrusions of S.W. Scotland."

(*a*) An unrecorded member of the Carboniferous suite intrusive into red sandstone of Upper Old Red age. Its maximum width is 7 ft. 3 in., and it comprises two members, both of porphyritic olivine-basalt. The second is chilled against the first and has altered it. Zones of slickenside and shattering show that movement has taken place after its intrusion. The central member is highly porphyritic, often vesicular, and contains inclusions of a fine-grained basalt. The country rock is decolourized for 2 feet from the margin and its calcareous cement is largely replaced by silica laid down in optical continuity with the original quartz grains.

(*b*) The petrology of the following intrusions is described:—Barncorkrie, Glenluce, Carsebuie, Barnaight, Doon Hill, Kirkinner, four near Creetown, Mid Burn, Mid Hill, Knockgray, Cairnsmore of Carsphairn, Harg Hill, Cairngarroch, and Knockencur. The first is the most basic, olivine appearing in one of its phases, and the last is the most acid. The others vary between tonalite and diorite, augite-biotite-diorite being very common.

In connection with the tectonics of the region a N.E.–S.W. alignment of the plutonic intrusions is pointed out. The Merrick and Kells mass is considered to have been two intrusions subsequently joined. The metamorphosed areas without any visible igneous contact show the same disposition, and coincide with the strike of the Lower Palaeozoic sediments.

YORKSHIRE GEOLOGICAL SOCIETY.

17*th March*, 1928.

H. C. Versey, M.Sc., F.G.S.: "The Structure of the Howardian Hills and Adjacent Areas."

The Howardian Hills form a very complicated tract of country south-west of Cleveland and are dominated by two fault systems which cross at an angle of approximately 60°. Experimental evidence is adduced to show that such an arrangement could be the result of two pressure directions, one of which was accompanied by torsion. One of these is that producing the Cleveland folds. The other is deduced (*a*) by examining the nodal character of the principal faults and (*b*) by plotting the levels along the strike of selected marine strata. Both these methods point to the existence of minor folds of Caledonian trend. Three periods of movement are suggested: (1) Intra-Jurassic, causing the anomalous thinnings of beds in the Coxwold area and controlling reef-formation in the Corallian; (2) Post-Jurassic and pre-Chalk, shown by the nature of the faulting and the epigenetic character of some of the drainage; (3) Post-Cretaceous, proved by the continuation of the faults into lines of disturbed Chalk. The relation of these movements to the Market

Weighton axis is discussed and the latter considered to consist of two distinct phases, an earlier one due to marginal recovery round the Cleveland sedimentation-subsidence and a later phase correlated with the Cimmerian of Germany. The bearing of the Howardian folds on possible deep-seated structures is examined with special reference to the northern boundary of the Concealed Coalfield of Yorkshire.

R. G. S. Hudson : " The Structure of the Craven Lowlands."

The Lower Carboniferous sedimentation of the Craven Lowlands was controlled by the position of the Lake District-Pennine massif and that of the Midland massif. The area of sedimentation was probably a branch of the main Mid-European Culm Sea deriving its sediment from the south-east as a result of early Hercynian movements in that area. There was progressive transgression on the flanks of the Lake District-Pennine mass in the Tournaisian, and final submergence in the early Viséan resulting in the formation of a lagoon area to the north of the deeper Craven Sea. The reef limestones are localized in roughly parallel belts of late C, S, and D age respectively, and were followed by uplift, the beginnings of which may have been responsible for the formation of the reefs.

The Clitheroe, Slaidburn, and Sykes anticlines are shown to be composed of a series of folds *en échelon*, mainly post-Carboniferous and pre-Permian in age but initiated in the Carboniferous. Minor folds of similar direction are present in the Carboniferous of the Craven Highlands. The Craven, Barnoldswick, and Clitheroe faults form a fault system which is later than the folds and includes the Barbon and Kendal faults south of the Lake District. The age of these faults is discussed : there is no evidence of pre-Permian movement. Physiographical evidence points to considerable movement of the Craven faults in the post-Cretaceous.

Mr. C.E.N. Bromehead gave a few notes on archaeological objects at York of interest to geologists and discussed the use of Magnesian Limestone and Millstone Grit in Roman, Saxon, and Norman times. A carved slab in York Minster was specially mentioned, as archaeologists differed as to its date. This stone has been identified by the Survey as Magnesian Limestone. All the churches in the district built in pre-Conquest times were of grit ; Norman additions of limestone, even when grit has to be carried a long distance and limestone was available on the spot ; the same applied to carvings. The geological evidence was, therefore, strongly in favour of the twelfth century date of the carving and against the pre-Conquest date urged by one prominent archaeologist.

OBITUARY.

John Horne.

BORN 1ST JANUARY, 1848. DIED 30TH MAY, 1928.

The little Stirlingshire village of Campsie where John Horne was born lies about 12 miles north of Glasgow, and it was in the High School and the University of that city that he received his education.[1] A natural bent towards geology led him at the age of nineteen to accept a post on the Scottish branch of the Geological Survey, and in this service he laboured for the long period of forty-four years. He retired in 1911 with a magnificent record of achievement and with a world-wide reputation as one of the foremost geologists of his day.

His active life falls roughly into three periods. The first of these covers the years up to 1883, during which he was proving his powers as a geologist furnished with rare gifts of observation and deduction, endowed with the still rarer faculty for seizing on and emphasizing the significant details of a problem, and equipped in addition with a terse and lucid style. He was largely engaged during these years in routine field-work, mapping large areas of country mainly in the southern and north-eastern counties of Scotland, while his well-earned vacations were spent in carrying out, in conjunction with his colleague, B. N. Peach, many important pieces of private research. It must always be reckoned one of the happiest chances that brought together in the service of Scottish geology two such alert and inquiring minds as those of Peach and Horne. Peach was the senior in age by six years and in service by five, and when in 1867 Horne was placed under him to be trained there began a partnership that went from triumph to triumph, a companionship in research that knew nothing of rivalry, a friendship that was to be interrupted only by death. In 1873 Horne spent his leave examining the rocks and glacial deposits of the Isle of Man and in 1874 summarized his results in a paper contributed to the *Transactions of the Edinburgh Geological Society*; perhaps the most striking feature of this paper is his insistence on the glaciation of the island by land ice filling the Irish Sea. In 1874 we find him and his colleague, R. L. Jack, investigating the glacial phenomena of the valleys of the Theiss and the Pruth, and the results of their observations were given in a paper ("Glacial Drift in the North-Eastern Carpathians") published in 1877 in the *Quarterly Journal of the Geological Society*. In 1876 he embarked along with Peach on a series of important researches on the glacial phenomena of the North of Scotland; their "Glaciation of the Shetland Islands" appeared in 1879, the "Glaciation of the Orkney

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[1] It is of interest to note that the first part of the *Transactions of the Geological Society of Glasgow*, published in 1860, was a valuable monograph on the "Geology of the Campsie District" by John Young, himself a native of the parish.

Islands" in 1880 (*Quarterly Journal*), and the "Glaciation of Caithness" in 1881 (*Proceedings Royal Physical Society, Edinburgh*). Of supreme interest in this series of researches is the demonstration of how the Scandinavian ice-sheet had overridden the Shetlands, coalesced with Scottish ice on the floor on the North Sea, and deflected the latter north-westwards over the Orkney Islands and the Caithness plain. The Old Red Sandstone and associated volcanic rocks of these northern islands also received full description at their hands in two valuable papers, "The Old Red Sandstone of Shetland" (1879) and "The Old Red Sandstone of Orkney" (1880), contributed to the *Proceedings of the Royal Physical Society of Edinburgh.* For his share in this work Horne was awarded in 1888 the Wollaston Fund of the Geological Society.

The second period may be dated as extending from 1883 to about 1901 and during this period the two friends carried through those brilliant investigations which were to win for them the homage of the whole geological world. It was in 1883 that Horne and Peach were sent to map in detail the Durness-Eireboll district of the North-West Highlands. The communication to *Nature* in 1884, in which they arrived independently at the same conclusions as Lapworth, definitely showed that Murchison and Geikie's views as to the structure of the North-West Highlands were untenable, that the quartzites and limestones of Durness were *not* conformably overlain by the eastern schists, and that there was the clearest evidence for repeated overfolds, powerful reversed faults and gigantic thrusts. The results of this preliminary work were startling, and it now became the task of Horne and his colleagues to follow the structures mapped in Durness south-westwards along the whole belt of complication. In 1888 came the carefully-drafted and confirmatory "Report on the Recent Work of the Geological Survey in the North-West Highlands of Scotland", in 1891 the discovery of the *Olenellus* fauna, in 1892 the classical paper by Peach and Horne in the *Quarterly Journal* in which the limestones and quartzites were assigned to the Cambrian, and the pre-Cambrian age of the great series of red sandstones and arkoses (given the formational name of Torridonian) definitely established. The great part that Horne played in these investigations brought him the award in 1892 of the Neill Prize of the Royal Society of Edinburgh and in 1899 the Murchison Medal of the Geological Society. During this period Horne was in addition supervising, and taking part in, the Survey work in North-East Scotland with his headquarters at Inverness, and in 1896 he collaborated with Mr. (now Dr.) E. Greenly in an important paper on the foliated granites of Strath Halladale in East Sutherland in which it was shown that the "foliation" was in this case due to the intimate penetration of a schistose rock by a granitic magma (*Quarterly Journal*). At intervals also between 1888 and 1896 he carried out with Peach and Macconochie a careful revision of the critical areas in the Southern Uplands, following up the classical researches of Lapworth, and the results of this work were embodied in the great memoir on the Silurian rocks of Scotland published in 1899.

The third period of Horne's active life may be said to begin when in 1901 he became Assistant Director in charge of the Survey work in Scotland. Mainly occupied as he now was with administrative and supervision duties he yet found time to carry on research. In 1903 he contributed in conjunction with Peach an important monograph on the Canonbie coalfield to the *Transactions of the Royal Society of Edinburgh,* while the two collaborated in an extraordinarily valuable contribution on " Scottish Lakes in relation to the Geological Features of the Country " to Murray and Pullar's " Bathymetrical Survey of the Scottish Fresh-Water Lochs " issued in 1910. It was during these years also that he saw much of his earlier work published. The classic memoir on the North-West Highlands of Scotland appeared in 1907 and every student of this volume must feel deeply grateful for the masterly summary which Horne supplied by way of introduction. In addition he contributed to various other important Survey memoirs—" The Neighbourhood of Edinburgh " (1910), " Glenelg, Lochalsh, and South-East Skye " (1910), " Central Ross-shire " (1913), " The Fannich Mountains and Upper Loch Maree " (1913), " Beauly and Inverness " (1914), " Caithness " (1914), " Mid Strathspey " (1915), " Lower Findhorn and Lower Strath Nairn " (1923). Fresh honours came to him: the Fellowship of the Royal Society conferred in 1900 was followed by his selection as President of the Geological Section of the British Association for the Glasgow meeting in 1901 (" Recent Advances in Scottish Geology ") ; in 1902 he received the LL.D. of Aberdeen University and in 1911 that of St. Andrews. In the latter year he retired from the Survey but freedom from official duties meant to him merely fresh opportunities for study and service. In 1912 he and Peach conducted a British Association excursion to the North-West Highlands[1]; it was the last time they were to visit the mountains they knew and loved so well, the mountains that, in Suess' fine phrase, they had made *transparent.* From 1915 to 1919 he was President of the Royal Society of Edinburgh and in 1917 he communicated to its *Proceedings* the results of the investigations made by Peach and himself on the well-known bone-caves of the Allt nan Uamh, near Inchnadamff; in 1921 he received the LL.D. of Edinburgh University, and in the same year was awarded (jointly with Peach) the Wollaston Medal of the Geological Society, the highest award that the Society has to bestow. His last years were active enough; he took a great part in the scientific life of Edinburgh; he was still busy on Survey work, and one of his greatest pleasures was to welcome the many distinguished geologists who came from all parts of the world to visit the North-West Highlands and who never failed to call on him to express their gratitude and their delight at what they had seen. He was also engaged on the preparation of a book on Scottish geology, undertaken in collaboration with Peach and intended as their last great gift to the science they had served so long and so faithfully. He lost Peach in January, 1926 (what the loss meant to him is beyond understanding), and carried on at this task alone, but the end came before it was complete.

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[1] A photograph of them outside the hotel at Inchnadamff, taken on this occasion by Professor S. H. Reynolds, appears in the GEOLOGICAL MAGAZINE for April, 1926.

Knowledge and service were the lodestars of Horne's life, and the brief account of his work that has been given shows how steadfastly and faithfully he pursued them. His generous nature, his wide sympathies, and his inspiring enthusiasm endeared him to all who were brought into contact with him. He loved to meet and mix with his fellow-workers both at home and abroad, to discuss their problems, and out of his own great store of experience and knowledge to suggest new viewpoints or fresh lines of attack. But still more did he love to have the young and the untried bringing to him their difficulties ; he was never too busy to welcome them and those who so sought him never failed to find encouragement and help. None knew better than he the pitfalls that beset the beginner, none knew better than he how to advise, to warn, and to praise. The world of geology is infinitely the poorer by his death but to all who had the privilege of knowing him he has left an imperishable and fragrant memory. And his friends the world over, thinking to-day of his untiring devotion to the pursuit of truth, of his patience, his sincerity, and his selflessness, of his unfailing courtesy and unwearying kindness to all, will be ready to say with the writer : A great gentleman and a great geologist has passed.

M. MACGREGOR.